Meadow restoration on former agriculture land in southwestern Ontario, Canada

by

Jennifer H.T. Balsdon

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Best practices for Restoration Ecology have been largely derived from case studies. Novel Ecosystems is an approach that has the possibility of providing the field of restoration research with both structure and a road map for ecological recovery. In December 2015, Ontario Parks will be ceasing the lease of approximately 122 ha of farmland within Boyne Valley Provincial Park. My thesis aims to bridge the gap between social and ecological systems and build a resilient restoration project at Boyne Valley Provincial Park. My approach integrated the best case scenarios from each the social and ecological aspects to determine a restoration plan. From the social aspect, I chose the method photo-elicitation to bridge the communication gap between myself, the researcher, and the interviewees. Semi-structured interviews were conducted with six major stakeholders including a farmer who is currently leasing land within Boyne Valley Provincial Park, a frequent hiker of the Ontario Parks' trail system, an academic researcher for Ontario Parks, and three Ontario Parks' personnel to understand the different landscape preferences of stakeholders within Boyne Valley Provincial Park. From the ecological aspect, I examined the success of restoration for the first year after a fall planting in terms of species richness and percent cover for all species, including native species (planted and not planted) and non-native species across three fields with different initial conditions. To test which species should be used as the initial ground cover after farming has ceased, I looked at the survivorship and growth of five species: *Danthonia spicata*, *Elymus trachycaulus* ssp. *trachycaulus*, *Sporobolus cryptandrus*, *Monarda fistulosa* and *Penstemon hirsutus*. My recommendations for restoration at Boyne Valley Provincial Park include implementing the restoration efforts at a smaller scale to start. The remaining fields should continue to be farmed until restoration can commence or mowed at least four times a year before seeds are formed. Open communication should continue between all stakeholders. Soil preparation should include tilling the soil prior to planting only if the land was left abandoned (e.g. old-field). A plant composition survey should be conducted prior to restoration – more particularly in hay fields - to determine if native meadow species are found. If native meadow species are present (e.g. *Sisyrinchium montanum*) that would not survive tilling, a no-till planting method may be a better option than tilling. Acknowledging these are early results, my initial recommendation based on survivorship and growth for the first year after planting would be to use plant plugs for *Elymus trachycaulus* ssp. *trachycaulus* and a combination of plant plugs and seeds for *Monarda fistulosa* and *Penstemon hirsutus*. Future studies should incorporate other herbaceous species to increase the biodiversity while choosing flowers that bloom at different times. Additionally, pilot studies should be completed at all Ontario Parks locations where agriculture leases are ending to develop restoration methodologies that are applicable across Ontario. Information on each of the species to be planted should be distributed to the farmers that border Ontario Parks' boundaries. This information should include at minimum the species life history, dispersal mechanisms, and a photograph. The research in this thesis outlines initial restoration efforts to guide restoration recommendations for the first year after land abandonment. Much longer-termed research is necessary to understand community dynamics and potential recovery of system.

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Introduction

Southern Ontario is the most densely populated region of Canada (Allen et al. 1990). Pre-European contact in the Great Lakes Region (400BP; Storck 2004), the landscape of southern Ontario was historically a mosaic of forests, wetlands, prairies and meadows (see Figure 1 in Delaney et al. 2000); however, through urbanization and agriculture land use, much of the natural landscape has been destroyed (McAndrews 1988; Szeicz and MacDonald 1990; Daigle and Havinga 1996; Munoz and Gajewski 2010). Habitat destruction has caused and is continuing to cause species extinction (Tilman et al. 1994; Pimm and Raven 2000; Waldron 2003).
A general global trend is showing that species local to an area are being replaced by non-native species and a few generalist species that have the capability to thrive in human-altered environments (McKinney and Lockwood 1999). Restoration of plant communities will be a challenge, although necessary, in the face of introduced species and changed environmental conditions (Myers and Bazely 2003; Suding et al. 2004).

Humans have a long history of land abandonment (Foster and Motzkin 1998; Cramer & Hobbs 2007). As land cover classes on earth becomes increasingly dominated by human uses (Vitousek 1997), there is increasing abandonment of what were intensively managed agriculture lands as shown in historical cropland inventory data (Cramer & Hobbs 2007). In eastern North America, land abandonment increased starting in the 1870s with improved transportation and the availability of agricultural goods from other areas (Cramer & Hobbs 2007). Cramer and Hobbs (2007) discuss and review the different types of land abandonment globally and regionally, but the overall picture indicates increasing levels of land abandonment in most parts of the world.

In eastern North America, of the ecosystems that have declined in area by more than 98% since pre-European settlement, 55% are grasslands (no trees), savannah (open communities of native grasses, wildflowers and few trees), and barren communities (shallow soils; Askins 2001; Thompson & DeGraaf 2001). The philosophy of restoration and understanding of natural communities by planting native species from the landscape started with prairies in 1934 at the University of Wisconsin by Aldo Leopold (Leopold 1949; Losin 1988). In the USA, initially, restoration activity primarily concentrated in prairie habitats, and subsequently expanded to include wetland habitats and by the 1980s woodlands were also being restored (Waldron 2003).

Prairies and meadows are similar plant communities with shared species (Daigle and Havinga 1996; Delaney et al. 2000). In North America there has, to date, been little restoration activity carried out in habitats that are explicitly designated as meadows. The main topic of this dissertation is meadow restoration. One of the main reasons for the absence of restoration of meadows is the absence of peer reviewed literature that recognises the presence and distinctiveness of meadow ecosystems in North America.

What is a meadow ecosystem?

Very little information exists on meadow ecosystems in North America. One of the first and only accounts is in William Bartram's (1791) travels in the America South between 1773 and 1777 where he gives a description of historical species composition for meadow ecosystems. For example, Bartram (1791) writes "*Observe these green meadows how they are decorated; they seem enameled with the beds of flowers*," and continues to list the vegetation he sees. This view described by Bartram (1791), even with species differences in different areas, are lacking from Ontario's landscape.

In North America, the literature is confusing in defining how prairies are functionally different from meadows. For example, both Packard and Mutel (1997) and Delaney et al. (2000) have the definitive criterion that fire is an important positive feedback system for the growth of prairies (Packard and Mutel 1997). In defining meadows, Delaney et al. (2000) state that meadows are maintained through processes such as flooding or drought; however, they do not refer to the impact of fire as a disturbance on a meadow. Trying to differentiate through soils, prairies plant species establish well on nutrient-poor soils but have the ability to establish on a wide range of soil conditions (Packard and Mutel 1997) whereas soil conditions for meadows in North America have not been defined. The bottom line, there is no clear definition based on species composition, disturbance regime or soil that distinguishes meadows and prairies. But nevertheless, there is recognition that meadows and prairies are different; however, there needs to be multivariate analysis to quantify the amount of variation between the two communities over space and time.

The existence of meadow ecosystems have longed been recognised in Europe and intensively studied and restored (Garcia 1992; Rodwell 1992; Smith et al. 2003; Table 1-1).

Table 1-1: Definitions of meadow ecosystems in the United Kingdom (adapted from Rodwell 1992)

Classification	**Definition**	**Plant species**
Mesotrophic grassland communities (5 categories of mesotrophic grassland)	Closed swards on drought-free mesotrophic to nutrient-rich mineral soils with a pH of 4.5-6.5 throughout British lowlands with fairly moist and mild climate and a long growing season. Anthropogenic lowland grasslands with some mire and water-margin communities in western Europe and the northern Mediterranean.	*Dactylis glomerata* *Festuca pratensis* *Festuca rubra* *Holcus lanatus* *Poa pratensis* *Poa travialis* *Cerastium fontanum* *Plantago lanceolata* *Ranunculus acris* *Trifolium repens*
Well-drained permanent pastures and meadows (Category 2 of mesotrophic grassland)	Closed swards of grasses and herbaceous dicotyledons and include the bulk of the permanent agriculture grasslands used for grazing and hay production in Britain. Additional species include *Cynosurus cristatus* *Lolium perenne* *Bellis perennis* *Leontodon autumnalis* *Taraxacum officianale*	*Leontodon hispidus* *Centaurea nigra* *Lotus corniculatus* *Trisetum flavencens* *Luzula campestris* *Ranunculus bulbosus* *Rhinanthus minor* *Leucanthemum vulgare* *Hypocheoris radicata* *Primula veris*

Classification	Definition	Plant species
	Indicative of older, unimproved, well-drained mesotrophic grasslands in Britain and include the bulk of Britain's rich and colourful meadows. Subjected to grazing in into the late spring and to agricultural improvement by the application of artificial fertilizers, ploughing, and reseeding, all of which tend to reduce the diversity of the swards and favour dominance of grasses	Unevenly represented *Anthoxanthum odoratum* *Agrostis capillaris* *Rumex acetosa*

A meadow in Europe is grassland that is mowed for hay, and then grazed as a pasture for the rest of the season (Rackham 1986). They are termed semi-natural vegetation meaning the plants in the meadow have not been sown but they are maintained by civilization through grazing or mowing (Rackham 1986). Many of these meadows (semi-natural grasslands) have disappeared through neglect, especially irrigated meadows that required a lot of attention to detail, or changed through fertilizer and weed killer (Rackham 1986) and efforts are being made to restore these ecosystems (Walker et al. (2004b)). Current meadows in Europe more closely resemble sown grassland where they are re-sown every ten years or so and are treated similarly to an arable crop of annual grasslands (Rackham 1986). This is not the case in North America where the concept of meadow ecosystem is rooted in practitioner's experience (Daigle and Havinga 1996; Delaney et al. 2000).

For the purpose of this dissertation, I am distinguishing a prairie from a meadow ecosystem as follows:

1. I consider prairies as a more stable plant community that is maintained by regular disturbance, ideally fire, from a management perspective.
2. I consider meadows, and indeed this appears to be in line with the prevailing views of North American restoration ecologist, to be transitional communities between grassland and a forest; in other words, there is an absence of disturbance that would maintain a prairie.

Currently, prairies and meadows are some of the most altered ecological communities in North America (Delaney et al. 2000). As many as 36 species at risk in Ontario (as listed on the provincial *Endangered Species Act, 2007*) require prairie and/or meadow habitats during some component of their life cycle (see Chapter 4 - Appendix A).

The Ecological Land Classification used in Southern Ontario as a qualitative description of ecosystems classifies meadow ecosystem as cultural meadows, which are old fields populated with non-native species (Lee et al. 1998). The lack of native species found in cultural meadows (Daigle and Havinga 1996; Crowder et al. 2007; Murphy 2010; Suffling and Murphy 2010) in southwestern Ontario requires an approach which recognizes that historical fidelity is not always an appropriate objective in restoration. Our restoration will follow the 'novel ecosystems' approach. Novel ecosystems are defined as, "lands that range from ecosystems that retain some of the original characteristics with some novel elements to potentially none of the original characteristics with the system containing completely different species, functions, and interactions" (Hobbs et al. 2009).

Given the lack of clear quantitative characterisation of how meadow ecosystems differ over space and time from prairie, means a restoration choice will take into account a series of several factors, including location (see Figure 1 of Delaney et al. 2000), human preference, historical use, and landscape preferences. Management strategies for the area are another major consideration as prairies require a fire regime for maintenance, which may not be appropriate for certain locations.

Restoration, Succession and Ecosystem Assembly and Transdisciplinarity

Restoration is a broad term in ecology that describes a wide array of projects (Higgs 2003). Restoration fits under the theme of ecological restoration which is an ensemble of practices (Higgs 2003; Halle and Fattorini 2004; SER 2004). Ecological restoration is defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SER 2004). Although it is difficult to find a definition of restoration ecology that fits all projects, it can be generally thought of as the scientific process of developing theory to guide restoration and using restoration to advance ecological theory (Palmer et al. 2006). One of the main issues with restoration ecology is its lack of general concepts for transferring information from one situation to another, which demonstrates the need for a conceptual framework (Hobbs and Norton 1996; Halle and Fattorini 2004). The science of restoration was initiated by practical application (Jordan et al. 1987) and has more recently defined itself as a scientific discipline (Palmer et al. 1997). Restoration ecology has grown out of a combination of agriculture and ecology in 1935 at the University of Wisconsin under the direction of Aldo Leopold (Leopold 1949). Two projects led to this field of study when a farmland that was given to the university to be an arboretum was turned into a 24-ha of prairie and another farmland north of the university restored by Aldo Leopold himself.

The concept of succession is central to vegetation assembly and is the dominant conceptual framework for vegetation development in old fields (Crammer and Hobbs 2007). Succession theory itself has a controversial past. Succession was first described by Clements in which plant communities followed a path from a simple to a climax community (Clements 1916). This defines succession as direction and deterministic. An alternate view was developed by Gleason (1936) which viewed plant succession following multiple pathways of development - a stochastic process (Pickett et al. 1987). Complex nonlinear systems, such as ecosystems, can use deterministic and stochastic models to predict succession over a short time scale (Hastings et al. 1993; Crammer and Hobbs 2007).

Restoration ecology is prone to be derived on ad-hoc, case-by-case studies making transfer of knowledge difficult from one situation to another (Majer and Recher 1994; Hobbs and Norton 1996). An approach is necessary that can provide restoration research structure and guidance towards ecological recovery. A transdisciplinary approach is proposed by some authors to be used when dealing with the complexity of landscape change and the interrelatedness of natural and human systems (Slocombe 1993; Freemark 1995; Pickett et al. 1999; Naveh 2000; Fry 2001; Kinzig 2001; Pickett et al. 2004; Naveh 2005; Knight et al. 2008; Nassauer and Opdam 2008; Tress and Tress 2009). This is much easier said than done with issues stemming from confusion of terminology (e.g. interdisciplinary and transdisciplinary are sometimes used interchangeably (Lele and Norgaard 2005) to a lack of a well-defined and cohesive conceptual, theoretical, and methodological framework surrounding transdisciplinary research. I used the term transdisciplinary to define involvement of non-academic participants such as land managers, user groups and the general public to create new knowledge (Tress et al. 2009b). Effectively, many experiences and publications appear to achieve some form of integration in research - crossing disciplinary boundaries or at least stepping out of one discipline and using others.

There are several approaches that step out of one discipline while engaging multiple stakeholders including scientists and local residents: human security (Hoogensen et al. 2009; Tanentzap et al. 2009), ecosystem approach (Waltner-Toews et al. 2008), social-ecological resilience (Folke et al. 2004; Folke 2006; Walker and Salt 2006) and novel ecosystems (Hobbs et al. 2009). I propose the use of novel ecosystems as a conceptual framework for restoration ecology which offers a collaborative approach and understanding of what should and should not be done (Murphy 2013). In terms of long-term goals for ecosystem recovery, the concepts within social-ecological resilience have attracted my attention and are more fully discussed in the following section. For example, resilience explicitly encourages adaptive management thinking for change (e.g. climate). Resilience is currently defined in the literature as, "*the capacity of a system to absorb disturbance and re-organize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks*" (Walker et al. 2004a; Folke 2006).

Social-ecological Resilience as a Long-Term Goal for Restoration

In restoring land, the action is to alter the patterns of human behaviour and intervene to affect the goal of a best-case compromise/outcome for ecological and social benefits. Part of the challenge lies in the differences between the key dimensions: ecosystems are rooted in physical dynamics of time and space while social systems are based on symbolic construction and meaning (Westley et al. 2002). Collaboration between the two traditional academic disciplines is an ongoing challenge (Hobbs 2005; Lowe et al. 2009; Phillipson et al. 2009). In collaboration, ecologists tend to team with social scientists that deal also with quantitative data, such as economists, rather than finding ways to collaborate across fundamentally different scholarly disciplines (Lowe et al. 2009; Bazely et al. 2013). Furthermore, social theorists and ecological theorists have tended to ignore each other - from their technical language through to their theories and the root focus of the lines of inquiry. For example, the term 'resilience' may have different meanings to different people. The difference in usage compounded with different meanings based in the ecological resilience and social resilience literature provides a messy situation for social-ecological studies (see also Folke 2006). Bridging the disciplines would allow a concept like 'resilience' to mean similar things to everyone using it.

Resilience is about being persistent and robust to disturbances – this is neither good nor bad, but a property of the system. Folke et al. (2004) used the ball in a basin metaphor to describe ecological resilience and thresholds (Figure 1-1). The social aspect is the decision and choices by people that the system is in an undesired regime and the regime in which the restoration direction is chosen. The ball represents the state of the system which is constantly moving towards the bottom of the basin – equilibrium state of the system - although through external factors (e.g. climate change), will never reach the bottom. For example, the ball could represent the abundance of allelopathic plant species (e.g. *Phleum pratense*) within the ecosystem. The size of the basin represents the amount of feedback the system can handle before the shape of the basin changes (Figure 1-1.2) and the ball rolls into another basin (alternate regime). Having a high abundance of allelopathic plant species will keep the old-field from succeeding into a forest. This demonstrates a high resilience of the system (Figure 1-1). With restoration efforts, we can reduce the proportion of allelopathic plant species in the old-field, and over time, shift the ball into the alternate regime of a meadow ecosystem. As this is our desired ecosystem, we want to keep the resilience of the meadow ecosystem basin high.

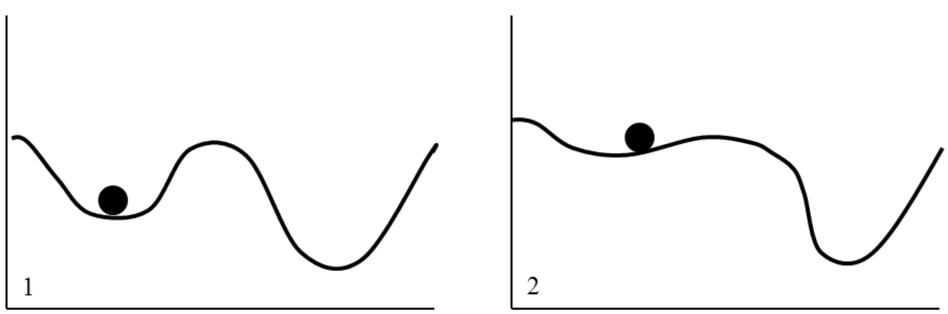


Figure 1-1: A two dimensional representation of a ball in a basin model. 1) Represents a ball in a high resilient regime and 2) represents a ball in a low resilient regime which can easily move into an alternate regime. (Adapted from Folke et al. 2004)

Several concepts that are pertinent to my thesis and will be discussed by topic: adaptive capacity, adaptive management, adaptive cycle, alternate regimes, and response and functional diversity.

Adaptive Capacity

Social-ecological systems are dominated by human actions (management; Walker et al. 2004a). Adaptive capacity is the capacity of the actors (people who influence a social-ecological system) to manage and influence the system (Walker et al. 2004a, Walker and Salt 2006). There are other definitions for adaptive capacity (e.g. Armitage 2005); however, the particular definition chosen provides a level of clarity for this research.

Adaptive capacity may include moving thresholds, meaning moving the current state towards or away from a threshold or making a threshold more difficult or easy to reach (Walker and Salt 2006). For example, when managers need to deal with a lake that has changed from a clear to turbid lake, the managers could change the state of the system by chemically immobilizing the phosphate in the lake (crossing a threshold) or phosphate levels could be reduced in the soil surrounding the lake (Walker et al. 2004a).

Adaptive Management

Adaptive management, characterized by learning through change (Lister and Kay 1999), attempts to apply the ideas of nonlinearity, unpredictability, and the element of surprise to resource management and uses components of resilience (Nadasdy 2007). A major challenge with the adaptive management approach is in trying to predict consequences of actions performed when the ecosystem is characterized by uncertainty (Nadasdy 2007). Managers need to be flexible and able to change practices in response to changes in the social-ecological system (Nadasdy 2007). A shortcoming of adaptive management is its tendency to ignore the broader political and economic context in which environmental management is embedded (Nadasdy 2007). Namely, conflict arises between modern extractive capitalist production, which demands a degree of short-term stability to recoup their investment, and resilience, which intrinsically seeks long-term planning (Nadasdy 2007). Short-term extraction decreases the resilience of the system creating more potential for the system to cross a threshold into an alternate state (Walker and Salt 2006).

Adaptive Cycle

Schumpeter (1950) view on economics was the first to describe the adaptive cycle with his views on periods of change, collapse, reorganization and renewal (Gunderson and Holling 2002). Holling applied Schumpeter's views to the ecological system (Holling 1973). The adaptive cycle is a heuristic tool focused on ecological succession that will help identify properties and processes to ultimately interpret events as well as provide ideas about the future system (Gunderson and Holling 2002).

The adaptive cycle is a general form and should not be used as a conclusive predetermined trajectory (Gunderson and Holling 2002). A graphical representation of the adaptive cycle is generally drawn as a figure eight with three axes: potential, connectedness and resilience (see Figure 2-2, Holling and Gunderson 2002). These three properties that have been observed to shape the future responses of the ecosystems, agencies and people include: the potential that is available for change (y-axis), the degree of connectedness between internal controlling variables and processes (x-axis) and vulnerability of the system (resilience; z-axis; Gunderson and Holling 2002). The adaptive cycle (the figure eight) consists of four phases of development: periods of exponential change (the exploitation or r phase), periods of growing stasis and rigidity (the conservation or K phase), periods of readjustments and collapse (the release or Ω phase) and periods of re-organization and renewal (the α phase; Gunderson and Holling 2002). It is important to note that this cycle evolves and changes through time as biological time flows unevenly, the r to k phase proceeds slowly in comparison to the quick and rapid Ω and α phase (Gunderson and Holling 2002). The overall idea is that as the ecosystem matures, relationships and links become tightly bound making it easier for external forces (e.g. wind, fire, disease, insect outbreak, etc.) that would normally be absorbed by the system to cause the system to pass the threshold into the next phase (Gunderson and Holling 2002).

The classic example that illustrates the adaptive cycle is the dynamics of spruce-fir forests in North America (Box 2-1, Gunderson and Holling 2002; Walker and Salt 2006). Within a single patch, the cycle begins at the rapid growth phase (r phase) of a young forest characterized by low needle density and predator-controlled budworms populations owing to their visibility. That forest patch matures in age until it achieves a stable predictable growth pattern (40 - 120 years; k phase) and high foliage conceals the budworm from their predators. Budworm larvae numbers surpass the ability of their predators to control them and an outbreak occurs killing a majority of the forest trees (Ω phase). The rapid decrease of trees presents new opportunities for plants to grow and re-establish (α phase). If the network of species, their interactions and the combination of structures persist, the cycle will likely repeat as described above, or if not, reorganise with a different adaptive cycle leading to an alternate state.

Alternate Regimes

Feedbacks, positive and negative, are information flows that regulate ecosystems (DeAngelis et al. 1986). A positive feedback reinforces change in the direction of the deviation (e.g. population increase) while a negative feedback keeps the system close to a steady-state (e.g. mortality; DeAngelis et al. 1986). An example of a positive feedback would be as biomass increases, soil increases and the total amount of available nutrients increases (DeAngelis et al. 1986). The negative feedback increase as succession proceeds, the gains from the positive feedback (nutrient increase) will decrease and the primary production will decrease with depleting nutrient levels (DeAngelis et al. 1986). The negative feedback acts as a stabilizing regulator of the system through keeping populations and communities from growing out of control, although there can still be sizeable fluctuations in populations (DeAngelis et al. 1986). One major challenge in restoration is that degraded sites have their own negative feedbacks that may keep the site in that state (resilient, although not a desired resilience; Suding et al. 2004).

Restoration activities need to account for the changed abiotic and biotic feedbacks in a degraded system instead of focusing on restoring historic abiotic features of the system (i.e. successional-based approach; Suding et al. 2004). Suding et al. (2004) gave several examples where relying on a successional-based approach will lead the restored system to an alternate state. Degraded ecosystems are known to have unexpected results often occur making it difficult to predict responses (Suding et al. 2004). From this, the system may need to exit the current adaptive cycle into another cycle before plantings should commence. Determining an empirical measurement of how long it will take to cross a threshold in a social-ecological system is still in its infancy and is mostly done through recognizing warning signs (e.g. Contamin and Ellison 2009; Brock and Carpenter 2010; Drake and Griffen 2010).

Abandoned agriculture fields are an example of alternate states in which the removal of the cause of degradation (farming) will not return the area back into the pre-disturbance conditions. Given the changed abiotic and biotic conditions within the leased Ontario Parks land, a novel ecosystem framework will be used for restoration on degraded land (sensu Hobbs et al. 2009).

Response and Function Diversity

Functional diversity refers to the range of functional groups a system depends on (Walker and Salt 2006). A functional group clusters species by traits that relate to ecosystem functioning (Naeem 2006). For example, different functional groups in an ecological system are legumes, grasses, micro and macro arthropods (Naeem 2006). Therefore, a grassland patch with 100 species of grasses has less functional diversity than a patch with one species of grass and one species of legume (Naeem 2006).

Response diversity is the range of different responses within a functional group (Walker and Salt 2006). For resilience of the ecosystem, the diversity of responses to events within a functional group is as important as the diversity of responses within an ecosystem (Elmqvist et al. 2003). The resilience of the system is enhanced with increased response diversity within a functional group. This does not imply that high species diversity equates to high resilience as species loss is often non-random (Elmqvist et al. 2003), but rather the existence of functional groups with different and overlapping characteristics in relation to physical processes help maintain an ecosystem in the same state (Folke 2006). Loss of response diversity within a functional group may lead a system to shift to an alternate state (Elmqvist et al. 2003). Elmqvist et al. (2003) gave an example in coral ecosystems where the loss of response diversity led to a shift in states. In a coral dominated system, if an area is subjected to overfishing of both top predator large fish and smaller herbivorous fish, this will decrease the response diversity within the functional grazers group (ie. lose the predator and herbivorous fish). Given the absence of herbivores, algae can overgrow and will eventually kill the adult coral colonies. The system will change from coral to algal dominance.

Objectives

The aim of this research is to explore restoration on former agriculture land in Boyne Valley Provincial Park in southwestern Ontario to a meadow ecosystem. The four objectives below are the objectives of Chapter 2-5 in this dissertation. Chapter 2-4 are data chapters with Chapter 5 synthesising the process of integrating social and ecological disciplines for restoration at Boyne Valley Provincial Park. The flow chart below will be used to explain the integrative process of social and ecological disciplines (Figure 1-2).

1. *Landscape preference:* The purpose of this exploratory research is to gain greater insight into landscape preferences through primary stakeholders in the planning process of restoration that will occur at Boyne Valley Provincial Park, Ontario.

2. *Plant composition*: To examine the success of initial restoration efforts following the planting and seeding of native meadow species on abandoned agriculture fields in Boyne Valley Provincial Park, Ontario.

3. *Survivorship and growth*: To identify a cost-effective restoration method for Ontario Parks, I tested the survivorship of the five species (*Danthonia spicata* (L.), *Elymus trachycaulus* (Link) Gould ex Shinners ssp. *trachycaulus*, *Sporobolus cryptandrus* (Torr.), *Monarda fistulosa* (L.), and *Penstemon hirsutus* (L.).) using established plant plugs grown at a nursery or sowing the seeds. This study focused on: 1) which treatment(s) and plant species had the best survivorship the first year after planting for plant plugs, seeds or a combination of plant plugs and seeds; and 2) which treatment(s) and plant species had the greatest growth for the first year after planting for plant plugs, seeds or a combination of plant plugs and seeds.

4. *Synthesis*: Provide a recommendation for Ontario Parks' restoration management plan for Boyne Valley Provincial Park based on the data collected in this research.

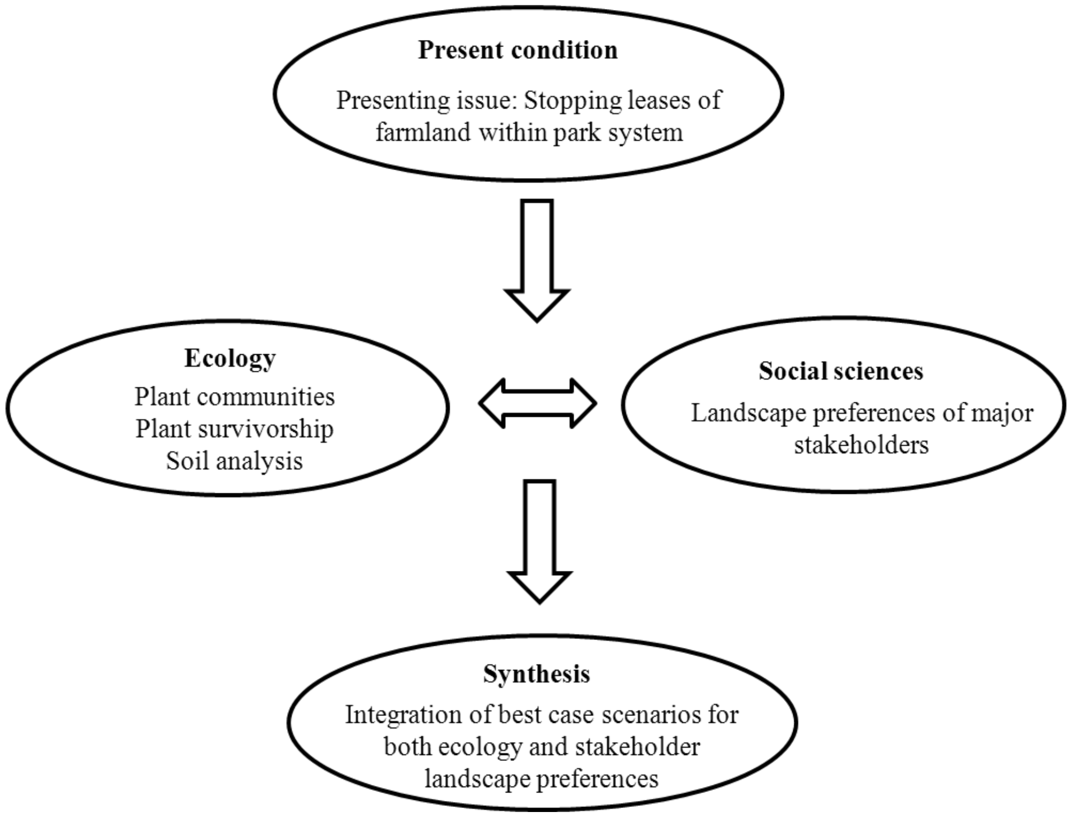


Figure 1-2: Scheme of integrating social and ecological disciplines for restoration at Boyne Valley Provincial Park. The horizontal arrow between Ecology and Social sciences represent the iterative thought process of the researcher to integrate the best case scenarios.

History of Boyne Valley Provincial Park

Ontario Parks is ceasing the lease of land within the park system in December 2015 across Ontario. Boyne Valley Provincial Park in Primrose, Ontario currently has an area totalling 121.99 ha under lease for agriculture. Resource limitation for the Ontario Parks systems requires a restoration management plan that will encompass the Parks' mandate to maintain ecological integrity within the park boundaries while being both practical and cost effective.

Farming in Boyne Valley Provincial Park dates back to at least 1938 (see Figures 1-3 to 1-6). Aerial photos of the agriculture fields within Boyne Valley Provincial Park (Figure 1-3) and the three experimental fields (Field 1, Field 2 and Field 5) are shown below. Farming will continue on private land which borders the leased agriculture fields.

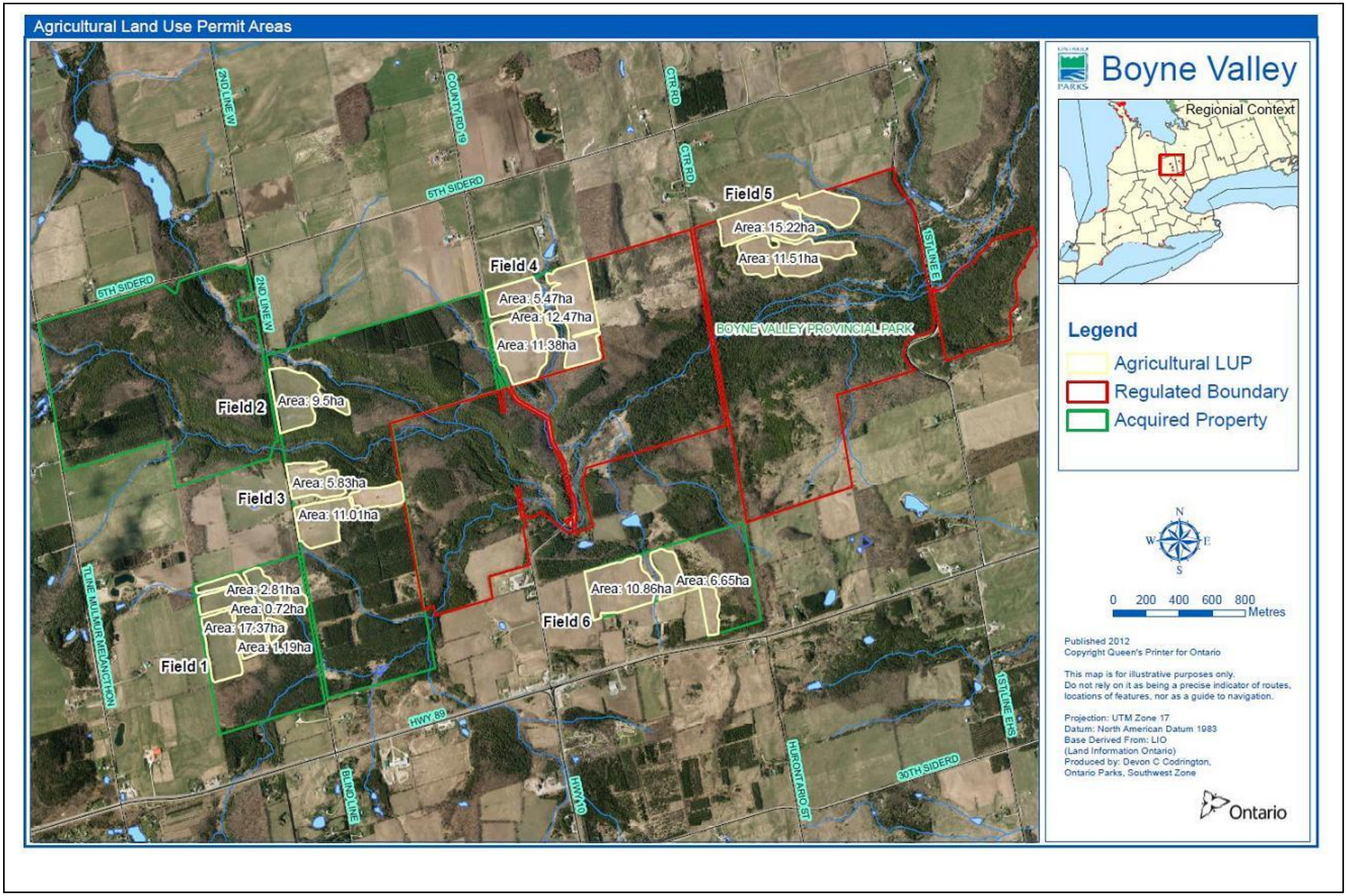


Figure 1-3: Boyne Valley Provincial Park outlining the regulated boundary area, acquired property and of the six agriculture land use permits (LUP) locations. This map was used with permission by Ontario Parks.

Figure 1-4: Historical 1938 photograph of Field 1 in Boyne Valley Provincial Park. Outline of Ontario Parks' current acquired property, leased land for agriculture use and experimental research location.

Figure 1-5: Historical 1938 photograph of Field 2 in Boyne Valley Provincial Park. Outline of Ontario Parks' current acquired property, leased land for agriculture use and experimental research location.

Figure 1-6: Historical 1938 photograph of Field 5 in Boyne Valley Provincial Park. Outline of Ontario Parks’ current acquired property, leased land for agriculture use and experimental research location.

Thesis Orientation

This dissertation is constructed in a manuscript style with a general introduction introducing the conceptual framework and goal for the research. The next three chapters are the exploratory research conducted with a final chapter synthesising the research as a whole. The following sections will briefly describe each of the chapters.

Chapter 1

This chapter provides a general introduction to novel ecosystems as a conceptual framework for restoration ecology and social-ecological resilience as the restoration long-term goal.

Chapter 2

This chapter discusses using the photo-elicitation method in conjunction with semi-structured interviews to understand major stakeholders' perspectives of the upcoming restoration on leased agriculture fields in Boyne Valley Provincial Park. The study did semi-structured interviews of six major stakeholders, defined as people directly involved with the restoration management plan of Boyne Valley Provincial Park, using seven photographs taken by the researcher as potential landscapes within the park.

Chapter 3

This chapter examines the success of restoration for the first year after a fall planting in terms of species richness and percent cover for all species, including native species (planted and not planted) and non-native species across three fields with different initial conditions. The three fields include an over 30-year old field, 7-years hay field and a field that has been in an annual crop rotation for at least the last few years.

Chapter 4

This chapter examines the survivorship and growth of five native plant species through restoration using plant plugs, seeds, or a combination of plant plugs and seeds. The five species are *Danthonia spicata*, *Elymus trachycaulus* ssp. *trachycaulus*, *Sporobolus cryptandrus*, *Monarda fistulosa* and *Penstemon hirsutus*. This is the first study to look at the survivorship of these species with the goal of restoring a meadow ecosystem.

Chapter 5

This chapter is a synthesis and provides a recommendation to Ontario Parks for their restoration management plan based on data collected from this research.

Contribution to Knowledge

Old fields have played a large role in developing insight into succession and ecosystem dynamics theories, which is central to the field of ecology (Cramer and Hobbs 2007). In restoration, this provides relations in understanding ecological succession or ecosystem assembly through studying ecosystem recovery (Cramer and Hobbs 2007). The classic model to understanding ecological systems changed in the 1970s with a transition from deterministic succession to non-equilibrium dynamics. Restoration ecology is in need of a framework (Hobbs and Norton 1996). Using novel ecosystems as a framework for restoration, this will provide a structured approach towards ecosystem recovery. My research will investigate the integration of social and ecological disciplines the first-year after plantings to better understand restoration of meadow ecosystems in southwestern Ontario.

There is a definite emphasis to restore idle/marginal/abandoned agriculture land to forests in southern Ontario. This research will provide an alternative to forest and prairie restoration. Given the current rarity of meadow ecosystems, low cost of planting meadow plant species compared to forest plant species, and their low maintenance regime compared to prairies, this research encourages future restoration projects to use a meadow ecosystem as a goal on abandoned agriculture fields.

This research provides a critical contribution to science in three specific ways:

1. Bridging the gap between the social and ecological disciplines through using novel ecosystems as a conceptual framework for restoring meadows ecosystems from former agricultural lands.
    a. Integrating landscape preferences goals from photo-elicitation interviews and ecological data in an iterative process.

2. Contribution to the academic and restoration communities through novel research: the pioneer scientific study to examine ecological restoration techniques to restore a meadow ecosystem (novel ecosystem) from former agriculture lands.
    a. Testing soil preparation techniques for success on ecological restoration.
    b. Testing ecological restoration techniques on success of initial plant community, and success of survivorship and growth of planted species.

3. Helping to develop restoration management guidelines for meadow restoration within Boyne Valley Provincial Park, through both social and ecological perspectives.

Chapter 2. Case-study using photo-elicitation in restoration planning at Boyne Valley Provincial Park: landscape preferences

Abstract

In December 2015, Ontario Parks will be ceasing the lease of approximately 122 ha of farmland within Boyne Valley Provincial Park. The intent of this pilot study is to provide a guide for Ontario Parks' personnel to understand the different landscape preferences of stakeholders and potential issues to address, in terms of communication, about the changes that are going to occur within the park. I chose the method photo-elicitation to bridge the communication gap between myself, the researcher, and the interviewees. Semi-structured interviews were conducted with six major stakeholders including a farmer who is currently leasing land, a frequent hiker on the trails in the park, an academic advisor on the restoration plans, and three Ontario Parks' personnel. Seven photographs depicting landscapes currently within the park, potential landscape for the restoration area, and a photo of one of the plant species used during the restoration experiment were shown to each stakeholder. From all the responses on the photographs, three themes were suggested from the interviews: 1) aesthetics; 2) stakeholder familiarity with Boyne Valley Provincial Park landscape and native species; and 3) functionality (Ontario Parks' Mandate regulations, workload for maintenance, and integration of farmland and Parks' land). From these themes, recommendations for Ontario Parks include restoring with native species, include wildflowers, give information (including a photograph and method of dispersal) of all newly planted species to all stakeholders and include all stakeholders throughout the restoration process. Given the novelty of meadow ecosystems, it may be best to restore lands in smaller increments rather than the entire 122 ha of land at once.

Introduction

Ontario Parks leases approximately 122 ha of land within Boyne Valley Provincial Park to four local farmers. This agreement expires December 2015 and Ontario Parks is currently developing a restoration management plan for the soon-to-be retired agricultural lands in order to meet their mandate for ecological integrity. The *Provincial Parks and Conservation Reserves Act, 2006* defines ecological integrity as, *"…a condition in which biotic and abiotic components of ecosystems and the composition and abundance of native species and biological communities are characteristic of their natural regions and rates of change and ecosystem processes are unimpeded"* (c.12, s.5(2)). This thesis provides Ontario Parks with recommendations and methodologies for the social and ecological restoration components of the restoration management plan at Boyne Valley Provincial Park. The social component of the restoration is addressed in the current chapter. The ecological component of the restoration is addressed in Chapter 3 and 4.

Restoration ecology inherently links social and ecological disciplines together. In restoring land, the goal is to alter the patterns of human behaviour to establish a best-case compromise for both ecological and social benefits. Restoration ecologists have to consider their personal values, aims and the concept of "good" restoration that will influence their choices for restoration goals as well as societal expectation (Higgs 2003; Hobbs et al. 2004; Hobbs 2007; Temperton 2007). Given the linked nature of social and ecological disciplines in restoring land, when stakeholders (e.g. local citizens) are excluded from the planning process of potential landscape changes, the on-going success (i.e. maintenance, respectful behaviour and reporting harm to sites) of restoration can be severely limited (Jordan 2000; Vining et al. 2000). This is particularly true when the potential restoration efforts may be in conflict with the landscape preferences of some of the stakeholders.

One may ask if understanding and including stakeholders is important. Based on the reactions to which stakeholders can object to being neglected or excluded from the process, the answer is '*yes*'. One of the most egregious situations has been the multi-stage Sagebush Rebellion in western United States of America (US). Graf (1990) depicted the historical and political aspects of the rebellion. The first stage of the rebellion revolved around the issue of irrigation lands and restrictive federal controls on public land. This part of the rebellion was resolved in 1891 with the *General Revision Act* shifting federal land policy from disposal and towards management (Graf 1990). This led to the second rebellion involving forested lands and then the third rebellion involving over grazed lands (Graf 1990). At this time, forested lands were regulated while grasslands were mismanaged and ruined for grazing (Graf 1990). From this, a "Grazing Advisory Board" was set up by the US government in 1934 whereby local stockmen assisted federal land managers in the management of the rangelands (Pellant et al. 2004). A brief resolution was met with the "*Taylor Grazing Act*" (1934), but failed to regulate grazing properly which led to the establishment of the Bureau of Land Management (BLM) that still exists today (Graf 1990; Pellant et al. 2004). Management recommendations to the BLM are provided by the "Resource Advisory Board" consisting of local advisories/citizens (Pellant et al. 2004). Their criteria for restoration are to apply a landscape-level approach to restoration, prioritize critical areas, pool financial resources internally and have public involvement in all phases of the restoration process, promote scientific research and studies to cost effectively, and successfully implement restoration projects (Pellant et al. 2004). Although this is an extreme situation, we can learn and apply some of the same criteria's from the Sagebush Rebellion to other restoration management plans. I addressed the public involvement part in this chapter, more specifically, the initial stage of understanding stakeholder's opinion on landscape changes.

Landscape perception studies can be used to understand stakeholder's preferences and one of the vehicles for this is to use photographs as the focus during interviews or surveys (e.g. Kaplan and Kaplan 1989; Ribe 2005; Van den Berg and Koole 2006; Howley 2011; van Marwijk et al. 2012). In fact, photographs of landscapes are the predominate method used to research landscape preferences (Kaplan and Kaplan 1989). These types of studies examine different preferences to help guide landscape planning (including restoration) for current and future uses/goals such as natural versus man-made environments (Balling and Falk 1982; Kaplan and Kaplan 1989; Hartig 1993; Hull and Stewart 1995; van Marwijk et al. 2012), biodiversity (Williams and Cary 2002; Pellant et al. 2004), policy (Williams and Cary 2002; Howley 2011), familiar versus unfamiliar landscapes (Lyons 1983; Dearden 1984), and improving stress-recovery in humans (Ulrich et al. 1991; Kaplan 1995).

Kaplan and Kaplan (1989) summarized 20 years of research for natural versus human-affected landscape preferences and concluded that natural landscapes are the preference in North America. The overall landscape preferences are related to landscape content, spatial configuration, and familiarity (Kaplan and Kaplan 1989; Penning-Roswell 1990). Kaplan and Kaplan (1989) also found that open landscapes were not preferred, likely relating to our instinct that areas with little protection are dangerous. As such, restoration of meadow ecosystems may not be favourable in terms of stakeholder's landscape preference as the ecosystems are both novel (unfamiliar) and open landscapes.

Within this domain, many studies have examined different factors that may influence a particular landscape preference. Attitudes towards landscape preferences are found to be place-specific and change with different user groups (Van den Berg et al. 1998; Howley 2011). Preferential landscape change may differ depending on education level and living environment (Yu 1995), knowledge of native ecosystems (Kaplan and Kaplan 1989; Ryan 2012), age (Kaplan and Kaplan 1989; Balling and Falk 1982; Lyons 1983; Zube et al. 1983), place of residence (Howley et al. 2010, Van den Berg and Koole 2006; Yu 1995), and occupation (Van den Berg et al. 1998; Dramstad et al. 2006). Concordantly, discerning landscape preferences is challenging as each person involved will bring his/her own set of values to the restoration project in question. Changes in the landscape will likely be easier for those not personally involved. Tress and Tress (2003) found that the unaffected outsider stakeholders showed preference for nature conservation, opportunities for leisure activities and/or expansion of housing; however, those living in the area of change found those alternative landscape options less favorable. Congruent with this finding, I expected to discover that there would be a difference in respect to the opinions about landscape preferences possessed by the stakeholders that live around Boyne Valley Provincial Park than those that live farther from the park boundary.

To guide Ontario Parks' restoration management plan, personnel will need to understand the different landscape preferences of stakeholders to know what to address in terms of communication and changes that are going to occur within the park system. The potential goal for restoration in the area is meadow ecosystems, a particularly underappreciated ecosystem in Ontario and North America in general. There is little reference for what a meadow constitutes in Canada because little documentation exists about this historic systems (Chapter 1). The reference point for meadow restoration for stakeholders is lacking and may be seen as undesirable for certain local landowners as a restoration goal. The purpose of this exploratory research is to gain greater insight into landscape preferences through major stakeholders in the planning process of restoration that will occur at Boyne Valley Provincial Park, Ontario. This exploratory research differs from descriptive research (case study description), correlational research (establishing connections between two or more variables) or explanatory research (establishing causal links through standardized protocols; Robson 1993). I used Robson's (1993) definition of exploratory research - inquiry that assesses phenomena through a new perspective or conceptual lens. To accomplish this, I have employed the method of photo-elicitation.

Photo-Elicitation

Photo-elicitation is based on the idea of using photographs as a method of gathering data on responses to aspects such as ecological state or management options in research interviews.

Combining the methods of images and words in an interview may evoke different views than a stand-alone face-to-face interview (Harper 2002; Clark-Ibanez 2004). Photographs can be researcher-produced or participants may take their own photos. In both cases, the photographs act as a means for communication, give structure to an interview, and acts as a tool to expand questions (Clark-Ibanez 2004). With researcher-produced photographs, participants will capture features within the photograph that the researcher may otherwise take for granted and overlook (Clark-Ibanez 2004) and provide comparability among the data obtained during each interview (Schartz 1989).

The method of photo-elicitation now used in social science was adapted from anthropologist John Collier (Collier 1957; 1967), which became the standard introduction to visual anthropology and sociology, with the expanded version (Collier and Collier 1986). The formal impact in anthropology may not be fully recognized as several studies published the use of photo-elicitation informally (Harper 2002). For example, Kaplan and Kaplan (1989) used photographs to evaluate landscape preferences, Balling and Falk (1982) used photographs (slides) to look at human preference of natural landscapes, and Herzog et al. (1976) use photographs to look at different urban spaces. Outside anthropology, photo-elicitation has played a large role in developing the field of visual sociology and has crept into other disciplines such as psychology, education and organization studies (see Harper 2002). More recently, photo-elicitation has made an appearance in publications about ecosystem management and land-use planning as a technique for planners to understand and engage the public/stakeholders (e.g. Balling and Falk 1982; Williams and Stewart 1998; Stewart et al. 2004; Glover et al. 2008).

In-depth interviewing is challenging when two people, the interviewer and interviewee, who have different cultural backgrounds need to communicate with one another - photographs can provide a bridge between communications as it is understood by both parties (Harper 2002) giving both interviewees something tangible to comment on instead of making them feel interrogated. Photographs should increase the understanding of the topic at hand to a common ground of both the researcher and participant (Harper 2002). Focusing on a stakeholders' landscape preference is not likely to eliminate conflicts but instead is a means whereby policies can uncover common values among stakeholders (Cheng et al. 2003; Glover et al. 2008). I chose to combine photo-elicitation with researcher-produced photographs in conjunction with semi-structured interviews to be able to allow for a qualitative comparison and contrast between the values of stakeholders relative to different types of landscapes in Boyne Valley Provincial Park, Ontario. Semi-structured interviews (Denzin and Lincoln 2005) were chosen because a set of questions were pre-prepared to understand landscape preferences of stakeholders but interviewees were given the freedom to direct the conversation once started.

Methods

The study began with the researcher taking photographs within Boyne Valley Provincial Park depicting different landscape types and features: a forest, farmland, experimental research plots, an old-field and a native wildflower (*Penstemon hirsutus*) that was used in the ecological part of this research. One photo was taken outside of Boyne Valley Provincial Park, a prairie, as these ecosystems are more commonly known for restoration in Ontario. After the pictures were sorted and seven photographs were chosen (one of each of the landscape types above was chosen with a second old-field photograph showing differing plant species).

The second stage proceeded with one-on-one, face-to-face interviews with the use of photo-elicitation to foster discussion. The application for semi-structure interviews was approved by the Office of Research Ethics (ORE) at University of Waterloo (ORE #17931). Major stakeholders for this study were identified as persons who directly owned/leased, used, and/or made the regulations of the land that was going to be restored within Boyne Valley Provincial Park. There are a total of four (4) famers who lease land within Boyne Valley Provincial Park, eight (8) Ontario Parks' personnel who are involved with the final decision of restoration that will occur within Boyne Valley Provincial Park and two academics who are working on restoration techniques within the park. The Bruce Trail borders some of the fields that will be restored and the viewpoint from a hiker was added to the list of participants. Of these potential participants, a total of six (6) stakeholders accepted the invitation to participate across a 4-month time period from February to May 2012. I categorised the 6 participants according to their relation and involvement with the restoration that will occur at Boyne Valley Provincial Park. Participant 1 (Researcher) was a researcher from the academic community working on restoration techniques in Boyne Valley Provincial Park, Participant 2 (Farmer) was a farmer who farmed leased land in Boyne Valley Provincial Park that will undergo restoration, Participant 3 (Hiker) was a hiker that frequently hiked the Bruce Trail going through Boyne Valley Provincial

Park and Participants 4, 5 and 6 six were Ontario Ministry of Natural Resource (OMNR) personnel who are involved with Boyne Valley Provincial Park to some capacity.

Each semi-structured interview consisted of a series of open-ended questions. The initial questions were geared towards the researcher gathering an understanding of the involvement of the stakeholder at Boyne Valley Provincial Park. The general outline of questions asked by the researcher were as follows:

1. Would you describe the history of Boyne Valley Provincial Park?
2. How long have you/or your family been/lived in this area? How long have you been involved in Boyne Valley Provincial Park?

The second sets of questions were geared towards the researcher gathering an understanding of the sentiment the stakeholders had towards Boyne Valley Provincial Park. The general outline of questions asked by the researcher were as follows:

1. What makes this area special/home to you? Why is Boyne Valley Provincial Park important for you to be involved in?
2. Tell me a story that will help me understand how special this place is to you? Why would you want to restore this area? To what? Why?

The next set of questions pertained to the seven photographs. Each participant was asked to describe his/her perspective of the photograph relative to the landscape and their desire to see what was presented in the photograph within the landscape of Boyne Valley Provincial Park. The general outline of questions asked by the researcher were as follows:

1. I have seven photographs showing different landscapes. Describe what you think of each photo? If you have any questions about the photos, let me know.
2. Would this (the photograph) be something you would like to see the landscape transition into?
3. What comes to mind when you look at each landscape? Do you like the photo, why or why not? Which photograph would you like to see in Boyne Valley Provincial Park?
4. What is it about the landscape (the photo they chose as their preference) that draws your attention?

The last set of questions were wrap up questions designed for the researcher to get an idea of the different perspectives and concerns the stakeholders may have about the restoration that will take place in Boyne Valley Provincial Park. The general outline of questions asked by the researcher were as follows:

1. What would you like seen done to the land that will no longer be farmed?
2. Do you have any concerns with the land changes that will occur?
3. Have you noticed any surprises with the restoration testing I have done in the area?
4. Any other comments?
5. Do you know of anyone else that would like to talk to me? Please give them my email and phone number.

The third stage of the research involved the researcher making a verbatim transcript of all six interviews. Once completed, the stakeholder's comments about each photograph were given to each participant giving them the option to elaborate and/or modify their comments.

Finally, the researcher organized the comments into common themes to better understand the landscape preferences of the major stakeholders at Boyne Valley Provincial Park.

Results and Discussion

The following seven photographs were used in the interview as a common focal point to combine and share the ideas and perspectives from all the major stakeholders (Figure 2-1A - G).

Figure 2-1: Photographs used in interviews include: (A) Coniferous forest along the Boyne Valley river; (B) After tillage of land before tarps were laid in June 2010; (C) Canola crop within Boyne Valley Provincial Park in 2011; (D) First year growth around research plots; (E) Location of an old homestead, (this is the same location as photograph D); (F) Photo of *Penstemon hirsutus* from one of the research plots; and (G) Restored prairie in Long Point Ontario.

Description of Photographs

All seven photographs were taken by the researcher. Below is a description of the reasoning for choosing the photographs for the interview.

Figure 2-1A - This photograph was chosen because this coniferous forest (Eastern White Cedar, *Thuja occidentalis*) is found throughout Boyne Valley Provincial Park along the banks of the Boyne River. Presenting the first photograph of a known feature in the area eased the awkwardness of the interview as well as the nervousness of a few participants about the whole interview process.

Figure 2-1B - The photograph of the experimental research plots was used to understand how the stakeholders viewed seeing experiments done within the park, beside a walking trail and neighbouring farmland.

Figure 2-1C - The photograph of the current farmland was to understand the different perspectives of what the park currently looked like.

Figure 2-1D - The photograph was taken of the experimental plot (same location as in Figure 2-1B) but one year after planting. The idea was to understand the responses stakeholders would have to what the land looked like 1-year after restoration efforts were implemented.

Figure 2-1E - This photograph was taken at the same location as Figure 2-1B and D but from the angle of the area that was left without tillage or planting.

Figure 2-1F - This is a photograph of one of the native planted herbaceous species (*Penstemon hirsutus*) in the restoration research plot. The purpose of this photograph was to understand the perspective of stakeholders viewing a new wildflower species in Boyne Valley Provincial Park.

Figure 2-1G - This is a photograph of a prairie restoration location in Long Point Ontario. The reason this photo was chosen was to show a different landscape that occurs in southern Ontario.

General Themes from Photo-elicitation Interviews

The notion that restoration was going to occur within the Park was accepted by all, but the choices for restoration were the main topics of discussion. For each photograph, participants were asked to comment on how they would feel if they saw what was in the photograph as part of the landscape in Boyne Valley Provincial Park. I, the researcher, observed three themes from the interviews: 1) aesthetics; 2) familiarity and native species; and 3) functionality (1. Ontario Parks' Mandate 2. workload associated with the upkeep of the restored land and 3. integration of Parks' land and neighbouring farmland sections). I have combined the themes familiarity and native species because the unaltered patches in the landscape in Boyne Valley Provincial Park consist of native species. Many of the comments can be categorized into all three themes, but I, as the interviewer, did the interpretation of the meaning of their comment from understanding the full context of their interview. Each theme is described below with excerpts from the interviews.

Theme 1 – Aesthetics

Restoration projects in the beginning stages may look unappealing with research plots, upturned soil and planted species mixed in with 'weedy' species. Given the changes that are going to occur within the park in the near future, I was interested in the stakeholder's viewpoint on aesthetics of the restoration process. Photograph 2-1B was the main starting point for the discussion with the tilled land and measuring tape showing the transect line.

Effective planning for landscape change at Boyne Valley Provincial Park should include understanding the stakeholder's perception of attractiveness and how this aligns with Ontario Parks' ecological mandate. Aesthetics and attractiveness of the landscape is an important starting point for formulating actions to affect landscape change (Gobster et al. 2007). Landscape aesthetic experience is defined as, "*a feeling of pleasure attributable to directly perceivable characteristics of spatially and/or temporally arrayed landscape patterns,"* (sensu Gobster et al. 2007). This definition by Gobster et al. (2007) includes both landscape aesthetic experiences (i.e. sight) and pleasure derived from recognizing ecological value (i.e. knowledge). Sight is the predominant sense that leads to a pleasing or displeasing feeling of landscape aesthetics, but Gobster et al. (2007) suggested that emotion-based processes (i.e. knowledge) may change a person's perception of the landscape change. This may not always be the case as in Hill and Daniel (2008) and van Marwijk et al. (2012) studies indicating that by providing knowledge about the landscape change alone was not sufficient to influence a person's perception of attractiveness.

Landscape features such as ephemeral features (flowers) can increase the positive experience for a hiker (Hull and Stewart 1995). The photograph of *Penstemon hirsutus* elicited similar responses by the stakeholders interviewed. To enhance this feature, native wildflowers should be planted within 15 m of the Bruce Trail as this is found to be the focal range for the majority of hikers (Hull and Steward 1995).

> *"Every year Bruce trail people do have wildflower hikes, and they do take their little books and they do look for flowers like that and they would love to see that. That would be very good"* (Hiker, Figure 2-1F)

> *"Definitely would be nice to look at … I believe the problem is people will start removing them if not looked after."* (OMNR, Figure 2-1F)

In accordance with Gobster et al. (2007), knowledge about the research and restoration effort was positive for the tilled experimental plot photograph (Figure 2-1B); however, as Hill and Daniel (2008) and van Marwijk et al. (2012) pointed out, knowledge did not change the perception of the land being aesthetically pleasing, but whether the landscape change was acceptable.

> *"…I have no problem with that because I know what's it there for and why it's there. And I know what will come back if it's managed properly, I don't have a problem with it…,"* (Farmer),

> *"Many hikers want to make sense of the things that they see along the Trail. If you put up a little sign, that tells people what's happening there, it would add a feature to the Trail,"* (Hiker),

> *"…I think that's a good thing, because obviously someone is doing research there… Yes so this is a very positive thing in terms of what native plant species will take here and what ones will self-propagate I guess, so yeah the research here, that's something I'd really want to see…",* (OMNR)*, and*

> *"I will assume this is one of your fields, that's a restoration field so this doesn't bother me because my assumption will be that it will progress into something else…"* (OMNR).

> *"…it's not permanent because it's research… it looks like just after leaf out…okay, so no I wouldn't have a problem with it, if that was July I'd have a bit of a problem with it. So context is important to me… I'd like to see a sign that says this is a research plot."* (Researcher; in the context that this is a provincial park and permanent research plots would contradict the *Ontario Parks Act*).

In this study, the appearance of the restored area was important to the stakeholders. Research plots were acceptable, but only if they were not permanent. Understanding and transferring knowledge of restoration plans to all stakeholders is very important, especially with the changes that will occur throughout the restoration process.

Theme 2 – Stakeholder familiarity with Boyne Valley Provincial Park landscape and native species

Meadow restoration will change the landscape in Boyne Valley Provincial Park to an unfamiliar ecosystem with new plant species. Showing photographs of current landscape features (Figure 2-1A and 2-1C) and potential landscapes after restoration was intended to assemble potentially different viewpoints on landscape change.

Different studies have shown landscapes to be considered more attractive for various reasons. For example, if the landscape change incorporates water bodies (van Marwijk et al. 2012), if the public perceives the restored land to contain more natural qualities (Kaplan and Kaplan 1989; Junker and Buchecker 2008) or to protect natural environment (Williams and Cary 2002), as well as higher plant diversity increasing the attractive of the area (Lindemann-Matthies et al. 2010). Throughout the interviews, I noticed that many of the comments about the photographs revolved around if they were looking at native plant species or not. The participants wanted to know whether the species shown in the photographs were native before their responses were given to their opinion. For example the Farmer said, *"…if it's all native, it is, yes, definitely"* (on Figure 2-1A) which contrasts the unfamiliar prairie system (Figure 2-1G), *"…not on my land"*.

> *"You know it's native, I don't have a problem with this, you need it for different types of wildlife. You can't just have a bush because not everything is going to survive; you need fields like this also. You do need a mix of both for the different types of wildlife."* (OMNR, Figure 2-1E)

Studies have found that familiar landscapes are positively correlated with landscape preferences (Kaplan and Kaplan 1989; Dearden 1984).

> *"when I am hiking I like to see forests broken by open fields because I am from the prairies and open fields are part of my heritage."* (Hiker, Figure 2-1C)

However, the landscape at Boyne Valley Provincial Park includes native species (Figure 2-1A) and for this reason, I could not distinguish in this study whether familiar landscapes were preferred because of the familiarity or because of the native status.

> *"..Looks terrible! It appears to be just an open field. No I'd like to see it like this picture (points to photograph A)… research plots are required to find what will and won't grow naturally and without these plot and studies we will not learn. I do not have a problem with research plots."* (OMNR, Figure 2-1B)

The interviews suggest that it is likely that planting native species will be preferred over non-native species; however, the unfamiliar landscape of meadow ecosystems may encounter resistance. Given the change restoration will pose on the landscape, a gradual change from farmland to meadow ecosystem (restore land in small sections) may encounter less resistance.

Theme 3 – Function of the land (Mandate regulations, workload for maintenance, and integration of farmland and Parks' land)

The change of land from farmland to a nature preserve will not only change the appearance of the land but the use and management of the land. I was interested in understanding how the restoration would be perceived in terms of the change or management on the land.

The third theme centered on the different possibilities of the restoration plan at Boyne Valley Provincial Park. I called this 'function' to describe the functional use of the land and divided the theme into three sections: 1) Ontario Parks' Mandate; 2) workload associated with the upkeep of the restored land; and 3) integration of Parks' land and neighbouring farmland.

Theme 3a – Function (Ontario Parks' Mandate)

Functional use of the land was defined differently by the participants. For example, the photograph of the canola field (Figure 2-1C) brought out different opinions of use of the land. Function in terms of policy and the Park Act was brought up,

> *"I don't object to farming or anything like that, I'm not sure it has a place in the park system frankly, there's lots of farm land for example so I'd rather see it become a meadow… Really shouldn't be farming on a park. It's not consistent with the Parks Act,"* (Researcher)

or its function in terms of productivity and livelihood,

> *"Definitely…",* (Farmer)

and its ecological function,

> *"…I would not like to see that in the long term for Boyne Valley, just because of the whole intact nature of that ecosystem…"* (OMNR)

From these three statements, we can already see a difference of opinion of how the land should be used and this should be considered in the restoration plan.

Theme 3b - Function (Workload for maintenance)

Changing the land from leased farmland to a nature preserve will increase the workload for Ontario Parks. I was interested in understanding their viewpoints on the increased workload in restoring the land.

Maintenance and workload associated with the landscape was important. Limitations from funding resources within Ontario Parks, leads to limitations on what can be accomplished for restoration in terms of maintenance and workload. Examples are from one of the old field photographs (Figure 2-1E),

> *"Cutting trail through tall grass has been a major work project in the Dufferin section of the Bruce Trail since 2008. We have 15 km. of trail in fields that have to be cut, depending on the pattern of rainfall, three times per year, if the hikers are going to be able to find the Trail. If this site has historical significance we should put up a sign that says so. If it is going to be overgrown by forest, it would be nice if it happens soon, because forest requires a lot less trail maintenance than grassland."* (Hiker)

and of the prairie ecosystem (Figure 2-1G),

> *"Prairies are a part of the ecosystem but the upkeep is something I don't feel I'd like to be involved in at this time."* (OMNR)

Given the limited resources available (manpower and funding) at Ontario Parks, a restoration plan with less maintenance and cost would be preferred. Meadow ecosystems are less expensive and require less maintenance than restoring a forest from bare soil, and will likely be favoured from this viewpoint.

Theme 3c - Function (Integration of Parks' land and neighbouring farmland)

Using photographs as part of the interview brought different perspectives to the foreground than just the face value of the photograph alone. For example, how the restoration would integrate into the landscape. The biggest concern raised (mostly from the Farmer and the OMNR) came from previous experience of land abandonment in the area and that once the leases ended, the land would be left to grow 'weedy' affecting neighbouring private farms that border the Parks' land.

Both the farmer and Ontario Parks' personnel were conscious about what happened when a parcel of land was previously left without any restoration efforts and that the 'doing nothing' approach was not an option. A few years ago, farmland was left abandoned in Boyne Valley Provincial Park and weeds infested both the abandoned farmland and the neighbouring private farmland creating both more work for the farmers and violating Ontario Parks' mandate of ecological integrity (Provincial Parks and Conservation Reserve Act 2006 (c.12, s.5(2)). Learning from history, Ontario Parks and the farmer do no not want a repeat of that event. This was evident in these next comments.

> *"… you have already started the project here where it is, it is not the greatest land like where we are but we just have to kind of, we're already in the process now, so carry on, but kind of how this probably came about, we had land up the road here, that was potato land and it had been leased for potato and crop and my brother had been leasing part of it and another farmer in the area, then the potato guy was doing the every other year, so they were basically rotating the land. And then somebody had the radar beacon, it was bought for the potato farmer, to put this beacon on for the airplanes going over and they, guidance systems, and they'd been leasing it for 10-12-15 years and they decided they were going to sell it, and somebody in Ottawa decided they weren't going to rent it anymore, they were going to sell it, they let it sit for 2 year, with no cover, no control of the weeds, that got to be a nightmare and I remember them telling us that as of 2010 they were going to eliminate all land use permits on this property and I basically told them, what's your transition plan, and they didn't have one…Once the land has been farmed for that many years, you have all that seeds that have come in over the years, they're there, and they stay dormant for a number of years. Wild oats will stay dormant for 50 years until they get the right condition to grow and once they get into an area, they're there, so you really have to work to get the out again. It's all kind of related to how, so this land has been farmed for a number of years, and this stuff is going to be there, you just have to do something to keep it under control, and they're maybe not native species, and they're going to compete against your native species to survive… you've got to put something there to keep it down and then you can go ahead. But just a cold turkey to say we're not renting it for farm land anymore, then you're exposing yourself to an issue with it and they're, your non-native species are going to be, take-over"* (Farmer, Figure 2-1F).

> *"…this is something that in the short-term is, like to see be taken out of the park, and let natural vegetation take over…concerns in the area, there were other government lands in the area that did have land-use permits on them … the land-use permits were cancelled but there was no plan in place … it was just left barren and then within 2 years the weeds there and*

> *most of them are what farmers consider noxious weeds and so within prime farm land you've got 200 acres of noxious weeds. That's where this study kind of came into place, we had to come up with a plan because definitely the local farmers don't want that happening with our property and we don't want it happening… we have to be good neighbours and that's the other thing that we have to remember is I'm here to manage the park but it's, I've got to work with the local community and neighbours and how we do it,"* (OMNR, Figure 2-1C),

Concern was raised by the stakeholders about the restoration process and how the Parks' land could potentially create more work for the farmer on their adjacent farmland. This requires continued conversation between Parks personnel and farmers throughout the restoration process to be aware of issues the stakeholder(s) may have.

> *"…Well this one I have more problems with, we have milkweed, and daisies, we've a little brome grass, that will help, but, there're a lot of weeds. This weed here is a bit of an issue… gets these other weeds into the hay then it's not salable because it's not what they want to feed to their animals. So milkweed is considered a noxious weed, it's very hard to control and it takes a lot of work, it is very difficult to control. And its seeds blow in the air like when the pods open, those seeds can go for miles and infest other people's property…"* (Farmer, Figure 2-1D),

> *"Yeah I suppose, I guess the milkweed there is always a concern with farmers. This to me looks much healthier than another area I saw here just left barren to grow… my concern there is the non-natives species once they set in, do they allow for native species to take over."* (OMNR, Figure 2-1D).

> *"…Once again, I don't really want to see the agricultural lands that are under permits now end up like this…it's concern that the, our neighbours who are farming their land are going to be worried about the noxious weeds here, the seeds blowing in, from a Parks' perspective when one of our main objectives and goals is ecological integrity, well non-native species dominating a site is not good for the Park, it's not what we do, where we want head."* (OMNR, Figure 2-1E).

Another concern that came out during the interviews was the species dispersal mechanisms. I had anticipated prior to the interview that the photograph of *Penstemon hirsutus* (Figure 2-1F), one of my native planted species used in my restoration research, to elicit discussions pertaining to ecological function and aesthetics during the interview. I, as the researcher, had seen the photograph as a positive visual. If I had only looked at the ecological side of restoration for recommendations, I would have likely missed the perspective that a new species being introduced into Boyne Valley Provincial Park, although native, may still cause anxiety to the stakeholder(s). Additionally, the importance of hay farming in the region was brought up. The concern with restoration was if an unknown plant species (e.g. *Penstemon hirsutus* used in the restoration species mix) mixes with the cut hay, other farmers will not to buy the hay to feed their cattle (i.e. the farmer loses the crop as a cash crop). Similar situations have occurred with non-native species known to grow in the crop fields in this region (e.g. *Cirsium arvense* and *Verbascum thapsus*) that have mixed with the cut hay. The same concern is with the native species *Solidago canadensis*. Although native, *S. canadensis* is known to dominate and acts as a 'weedy' species. If mixed with hay, it is very difficult for cattle to digest and the hay crop cannot be used as cattle feed and the farmer will lose the cash crop. This conversation led to the suggestion that information about each of the plant species used in the restoration area and the plant species dispersal techniques should be given to the surrounding farmers and to not use plant species that are dispersed by wind.

> *"Well, I don't know what the result of it's going to be, how it's going to take over. How it's going to affect the rest of the property, how it's going to affect, if it gets migrated into your hayfield, or whatever crop you have, what you are going to have to do to control it… and you don't know the adverse effects of them till you get them into the area… I don't think I could sell that if it was in the hay bale, so that's a concern…"*(Farmer, Figure 2-1F).

Given the novelty of meadow ecosystems in the area, having stakeholder involvement in all stages of the restoration are key to understanding the different perspectives. The next two comments indicated different perspectives from one photograph.

> *"that would be very pleasing, especially, and this is where as park interpreters and that, we have to get our interpreters and those type of folks out to do some public education and let them know, no this thing is supposed to be here… education is still the key because we get locked in our traditional ways of thinking and whether it's the farmers and their traditional agricultural background and that's where their mindsets is coming from and that's what they comment on and so, but we work together that way, but yeah education would be a key component, it would have to be."* (OMNR, Figure 2-1F).

> *"It's going to come down to capacity and what values we end up managing for. So, and, how much it threatens something else … if they start to take over a community that we value higher than that one species, then we may consider doing something about it… so monoculture wouldn't be very good, we've tried, we'd probably prefer not to see that"* (OMNR, Figure 2-1F)

Both the nature park reserve and the farmland have co-existed in this region for many years. With this long-standing relationship, involvement of all stakeholders, especially the farmers, in the restoration process is crucial for good relationship and continued support for Ontario Parks' restoration management plan.

Conclusion

This exploratory study using photo-elicitation and face-to-face semi-structured interviews with six stakeholders indicated that there are concerns about the upcoming landscape change relative to the restoration efforts within Boyne Valley Provincial Park. This case study was the first step in engaging the major stakeholders involved in the restoration process and enabling voices and perspectives that may not have otherwise been part of the management plan. A continuation of conversation flow between major stakeholders should be maintained to assess the restoration efforts and whether modifications are appropriate.

Recommendations for restoration at Boyne Valley Provincial Park that have come out of the interviews include the need for continued conversation with all stakeholders throughout the restoration process, use native species restoration, information to be given to all stakeholders about each of the plant species used in the restoration area including a photograph of the plant species and its dispersal techniques, and to restore in smaller increments to build familiarity of the restoration process and introduction of meadow ecosystems into Boyne Valley Provincial Park.

Future research could expand on this research by asking the stakeholders to take the photographs themselves. This will enable Ontario Parks to capture the meaning of the land (outside landscape preference which was the focus of this paper) by each person from their perspective. Ideas captured may include place, which can be physical locations such as the home, the neighbourhood or the park, but it also represents the meanings and emotions people associate with those settings (Davenport and Anderson 2005). These are often captured through narratives which can be used as a means to provide insight into the bond stakeholders have with the environment and putting this bond into the foreground (Glover et al. 2008). This gives planners a means to anticipate, identify and respond to the bonds people form with places (Glover et al. 2008). Using narratives to understand stakeholder's values helps to identify the diverse values for planners and land managers (Glover et al. 2008). Understanding local forces that shape the way people think about their community is a growing field aimed to improve a community's ability to make intelligent choices in land use development (Brandenburg and Carroll 1995; Bridger 1996; Glover et al. 2008; Kruger and Shannon 2000; Stewart et al. 2004; William and Stewart 1998).

Restoration will commence in Boyne Valley Provincial Park after December 2015. This research has used photographs to bring the stakeholders ideas, values and perspectives in the foreground of the planning process.

Chapter 3: Comparing restoration methods on the quality of meadow restoration on retired agriculture fields

Abstract

By the end of 2015, Ontario Parks is planning to halt the practice of leasing lands for farming within the park system. Ontario Parks will need a restoration management plan that will encompass Ontario Parks' mandate to maintain ecological integrity within the park boundaries while being both practical and cost effective. One approach is to manage for successional meadows because these are relatively inexpensive - especially at the whole-provincial scale - and ecologically feasible post-farming relative to immediate attempts to reforest. Additionally, the ecological benefits of restoring meadows are often ignored with the focus of restoration on other habitats (wetlands, forests and prairies). I examined the success of restoration for the first year after a fall planting in terms of species richness and percent cover for all species, including native species (planted and not planted) and non-native species across three fields with different initial conditions. Simpson's Diversity Index suggests that tilling and planting plugs was most beneficial at the over 30-year old field location (Simpson D of Plugs Only D=0.11; Simpson D of 1-year Fallow D = 0.62) while having little effect in the 7-years hay (Simpson D of range of all treatments = 0.16 to 0.17; Simpson D of 1-year Fallow D = 0.11) or the annual crop rotation fields (Simpson D of range of all treatments = 0.10-0.19; Simpson D of 1-year Fallow = 0.18). Mann-Whitney *U* comparisons were made between plantings consisting of tilling the land and planting established seedlings, planting seeds, or planting a combination of established seedlings and seeds versus leaving the field abandoned. Recommendations to increase native richness towards a meadow ecosystem in all locations would be to plant a combination of established seedlings and sowing seeds. Tilling had little effect in the annual crop rotation and is not recommended on the 7-years Hay field.

Introduction

Ontario Parks leases approximately 122 ha of land within Boyne Valley Provincial Park to farmers; this agreement expires December 2015. Ontario Parks is currently deciding on a restoration management plan for the forthcoming retired agricultural lands in order to meet their mandate of ecological integrity. The *Provincial Parks and Conservation Reserves Act, 2006* defines ecological integrity as, *"…a condition in which biotic and abiotic components of ecosystems and the composition and abundance of native species and biological communities are characteristic of their natural regions and rates of change and ecosystem processes are unimpeded"* (c.12, s.5(2)). Resource limitation (budget) for the Ontario Parks systems requires a restoration management plan that will encompass Ontario Parks' mandate to maintain ecological integrity within the park boundaries while being both practical and cost effective. This study will give Ontario Parks a starting plan to restore abandoned fields; however, generality will require the testing at many other sites across southern Ontario in the face of introduced species and changed environmental conditions (Myers and Bazely 2003; Suding et al. 2004).

Very little information exists on meadow ecosystems in North America. One of the first and only accounts is in William Bartram's (1791) travels in the America South between 1773 and 1777 where he gives a description of historical species composition for meadow ecosystems. For example, Bartram (1791) writes "*Observe these green meadows how they are decorated; they seem enameled with the beds of flowers*," and continues to list the vegetation he sees. This view described by Bartram (1791), even with species differences in different areas, are lacking from Ontario's landscape.

Prior to European contact in the Great Lakes Region (400BP; Storck 2004), the landscape of southern Ontario was historically a mosaic of forests, wetlands, prairies and meadows (see Figure 1 in Delaney et al. 2000). In North America, the literature is confusing in defining how prairies are functionally different from meadows (see Chapter 1). Bottom line, there is no clear definition based on species composition, disturbance regime or soil that distinguishes meadows and prairies. But nevertheless, there is recognition that meadows and prairies are different; however, there needs to be multivariate analysis to quantify the amount of variation between the two communities over space and time.

For the purpose of this dissertation, I am distinguishing a prairie from a meadow ecosystem as follows:

1. I consider prairies as a more stable plant community that is maintained by regular disturbance, ideally fire, from a management perspective.

2. I consider meadows, and indeed this appears to be in line with the prevailing views of North American restoration ecologist, to be transitional communities between grassland and a forest; in other words, there is an absence of disturbance that would maintain a prairie.

Presently, there is a gap in knowledge on how to restore meadow ecosystems in Ontario. As one of the first research projects explicitly focused on meadow restoration in Ontario, the intent was to begin the process of restoring ecological function on abandoned agriculture fields in Boyne Valley Provincial Park. One major challenge in restoration of degraded ecosystems is that unexpected results often occur making it difficult to predict responses (Suding et al. 2004). Unexpected outcomes may arise from restoration activities that focus on restoring historic abiotic features of the system (i.e. successional-based approach) and ignoring the changed abiotic and biotic feedbacks in a degraded system (Suding et al. 2004). Suding et al. (2004) gave several examples where relying on a successional-based approach will lead the restored system to an alternate state. Understanding that restoration at Boyne Valley Provincial Park is on abandoned agriculture land (degraded), the goal will be to restore the land to a novel ecosystem (sensu Hobbs et al. 2006).

Dispersal is known to be a factor limiting seeds distribution (Tilman 1997; Primack and Miao 1992; Bischoff 2002) and with few known meadow species in the immediate area surrounding the leased lands, it is unlikely that a meadow ecosystem will be restored without intervention. Furthermore, a seedbank investigation done in Boyne Valley Provincial Park on the leased lands indicate that the only viable species were non-native species (Pope et al. in preparation). This was not surprising as non-natives and weeds tend to be able to persist for long periods of time (Thompson and Grime 1979) whereas the ‘desirable’ species for grasslands tend to be lost when the habitat changes (Milberg 1995; Bakker et al. 2002). Mitlacher et al. (2002) found that many grassland species can survive less than a year in the seedbank with only a third being classified as short-term persistence.

The purpose of this research is to examine the success of initial restoration efforts following the planting and seeding of native meadow species on abandoned agriculture fields in Boyne Valley Provincial Park, Ontario. To my knowledge, no information is known about native meadow restoration making this research the pilot study on the plant composition after initial restoration efforts. The objectives are to investigate the effects of different restoration methods on the diversity, richness and percent cover of native and non-native plant species within the restoration areas. The restoration methods included tilling the land and planting plugs only, planting seeds only, and planting Plugs and Seeds. These planting methods were compared against a 1-year Fallow field (no tilling). Tilling the land before planting was applied to the treatment area as this is believed to eliminate dominant species (Daigle and Havinga 1996) and has been shown to increase species richness and percent cover with higher disturbance lowering seed predation (Mittelbach and Gross 1984). Accordingly, I hypothesize that native species diversity, species richness and plant cover will be greatest in the experimental treatments (planting plugs and/or seeds), whereas non-native species diversity, species richness and plant cover with be greatest in the 1-year Fallow treatment.

This research will allow for recommendations to successfully establish native meadow species during initial restoration efforts and provide direction for future restoration efforts in the Boyne Valley Provincial Park.

Methods

Study Site

Boyne Valley Provincial Park is located in Primrose Ontario, approximately 20 km north of Orangeville and 4 km east of Shelburne, Ontario. It is located within the Greenbelt, with the Bruce Trail, Canada's oldest and longest footpath that follows the Niagara Escarpment, meandering through parts of the park. The Greenbelt contains approximately 78,889 hectares of agriculture land (Tomalty 2012).Three of the six agriculture fields, Fields 1,2 and 5, had agreements with lease owners to allow part of the field to be used for experimental research (Figure 3-1).

Study Area

The area used for this experiment within each field was chosen with an Ontario Parks personnel and the lease owner to minimize disrupting farming activity. The smallest area was Field 5 (between two active crops) at approximately 150 m x 50 m (0.75 ha) and was used as the approximate sizing for Fields 1 and 2. Comparison of each of the three locations can be found in Table 3-1.

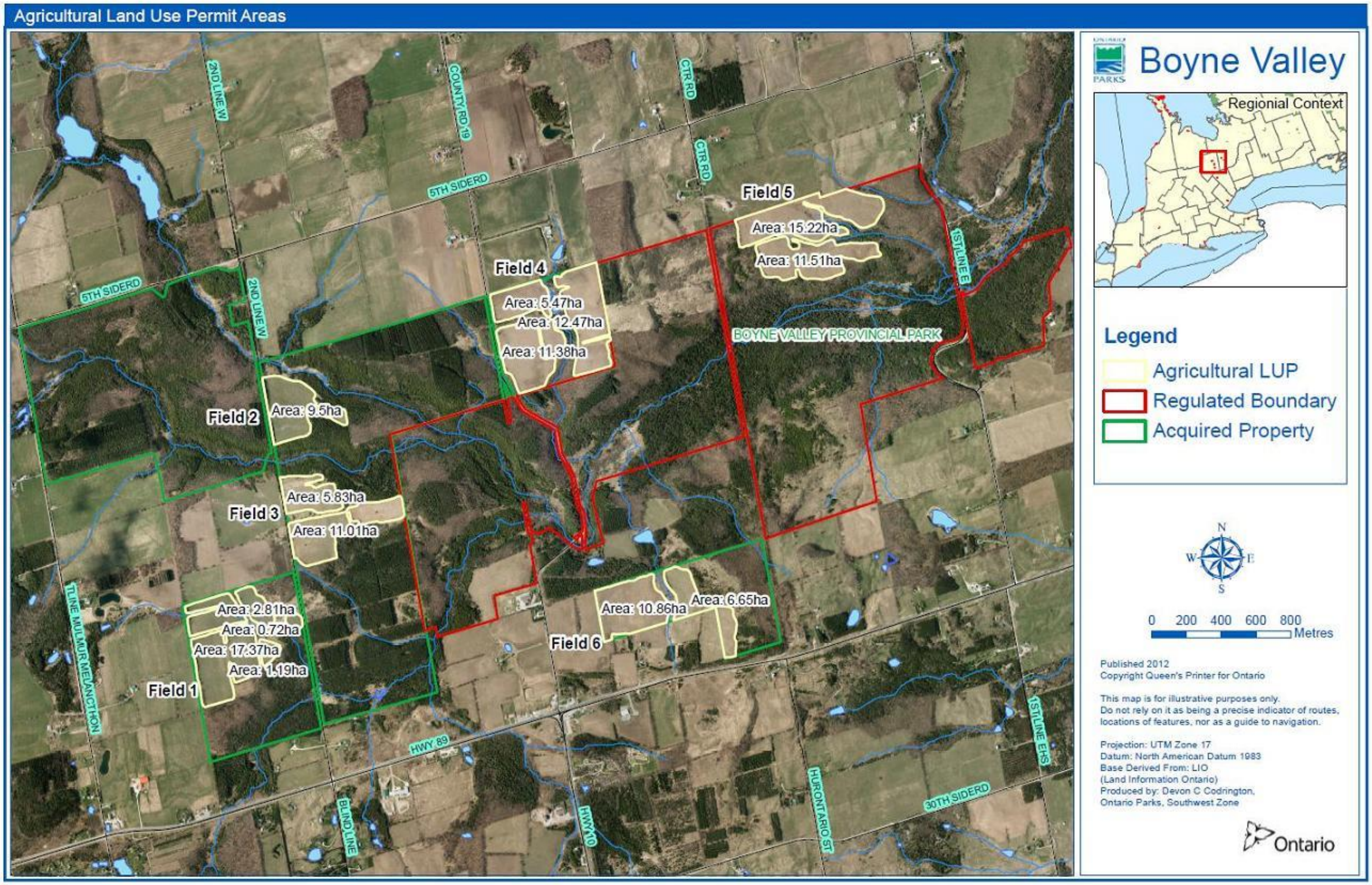


Figure 3-1: Boyne Valley Provincial Park outlining the regulated boundary area, acquired property and of the six agriculture land use permits (LUP) locations. This map is used with permission by Ontario Parks.

Table 3-1: Comparison of history, farming practices for years 2010-2012, surrounding landscape, and the Ontario Parks regulation status of the three experimental restoration sites in Boyne Valley Provincial Park, Primrose Ontario.

	Field 1 Over 30-year Old Field	**Field 2 7-years Hay**	**Field 5 Annual Crop Rotation**
Area of Ontario Parks	22.09 ha	9.5 ha	26.73 ha
Area of experiment	0.75 ha	0.75 ha	0.75 ha
History of the experimental field	Old homestead for at least 30 years surrounded by active hayfields	Active hayfield for at least 7 years	Rotation of corn, wheat, soy, and canola
Farming practice 2010	Experimental site with active hayfields surrounding the area	Experimental site with active hayfields surrounding the area	Experimental site with active wheat field surrounding the area
Farming practice 2011	Experimental site with active hayfields surrounding the area	Experimental site with active canola fields surrounding the area	Experimental site with active canola fields surrounding the area
Farming practice 2012	Experimental site with active hayfields surrounding the area	Experimental site with active wheat fields surrounding the area	Experimental site with active wheat fields surrounding the area
Landscape surrounding the restoration field	A mixed deciduous forest borders north side, non-maintained road on the east side, and farm fields on the south and west	*Thuja occidentalis* (Eastern White Cedar) forest borders its north-east and south-west sides with a farmed field on its north-west side On the south-east side is a mixed-forest. Approximately 100m north of Site 2 is a permanent cold water stream that runs west to east bordered by a mixed-forest.	A 0.25 ha *Thuja occidentalis* (Eastern White Cedar) forest on its south-west side with farmed fields bordering the rest of the site.
Ontario Parks Regulation	Unregulated land[a]	Unregulated land[a]	Regulated land[b]

[a] unregulated land meaning the area acquired by the Province for provincial park purposes and managed by Ontario Parks. Until such time as these lands are regulated under the *Provincial Parks and Conservation Reserves Act*, the act and its regulations are not applicable.

[b] regulated land meaning the area is owned by the Province and managed by Ontario Parks. The *Provincial Parks and Conservation Reserves Act* and its regulations are applicable and enforceable.

Note: Ontario Parks' management policies are applied to both unregulated and regulated lands.

Preparation of the Soil

Site preparation was based on protocols outlined in Daigle and Havinga (1996). Site preparation began with removal of existing vegetation for an entire growing season. On May 7th 2010, the three experimental field locations were initially tilled with an off-set disc tillage machine that tills approximately 6 inches deep. After tillage, blue tarpaulin was laid over each plot for the entire growing season (starting date: Over 30-year Old Field – May 7th 2010, 7-years Hay field and an Annual Crop Rotation field – May 16th 2010). Tarpaulin was used to trap heat and smother/kill plants and dormant seeds under the tarpaulin. Before the fall planting of the plant Plugs and Seeds, each transect was re-tilled using a hand rototiller on September 27th 2010. A fall planting was chosen to give the planted seedlings and seeds a chance at establishing in new soil in spring.

Planting of Plugs and Seeds

Five plant species, *Elymus trachycaulus* ssp. *trachycaulus* (slender wheatgrass), *Sporobolus cryptandrus* (sand dropseed), *Danthonia spicata* (poverty oatgrass), *Monarda fistulosa* (wild bergamot) and *Penstemon hirsutus* (hairy beardtongue), were grown at St Williams Nursery & Ecology Centre: Pterophylla Native Plants and Seeds. The established plant plugs seedlings and seeds were collected from the nursery and transported to the location of planting in Boyne Valley Provincial Park on September 24th 2010. The established plant plug seedlings and seeds were planted in all three fields between September 28th and October 2nd 2010.

Experimental Design

Five transects in a W-shape, to reduce autocorrelation (Forcella et al. 1992), were replicated at all three fields. Each transect was 32 m long 17 permanent plots per transect. Based on the area and dimensions available in each field, transects were placed to optimize area and were spaced a minimum of 5 m apart to reduce/eliminate seeds blowing to another transect. Each plot was 50 cm x 50 cm for a total area of 2500 cm^2 or 0.25 m^2. Description of the five transect are as follows:

Transect 1. *1-year Fallow*: This is the negative control transect in which the area was not ploughed for 1 year (Fields 2 and 5) and over 30 years (Field 1).

The soil for the remaining four transects were tilled, covered with tarpaulin and re-tilled before planting of the plugs and sowing the seeds:

Transect 2. *Plugs Only*: Each plot contains two plant plugs of *Danthonia spicata*, *Elymus trachycaulus* ssp. *trachycaulus, Monarda fistulosa*, *Penstemon hirsutus* and *Sporobolus cryptandrus*. Same species plugs were planted approximately 5 cm from one another.

Transect 3. *Seeds Only*: Each plot contains 0.6 mL x 2 of *Danthonia spicata* seeds, 0.6mL x 2 of *Elymus trachycaulus* ssp. *trachycaulus* seeds, 0.3mL x 2 of *Monarda fistulosa* seeds, 0.3mL x 2 of *Penstemon hirsutus* seeds and 0.6mL x 2 of *Sporobolus cryptandrus* seeds.

Transect 4. *Plugs and Seeds*: Each plot contains 1 plant plug of the 5 species listed above and 0.6 mL of *Danthonia spicata* seeds, 0.6mL of *Elymus trachycaulus* ssp. *trachycaulus* seeds, 0.3mL of *Monarda fistulosa* seeds, 0.3mL of *Penstemon hirsutus* seeds and 0.6mL of *Sporobolus cryptandrus* seeds.

Transect 5. *Control*: Tilled without planting plugs or seeds.

Vegetation Survey

In 2010, a general plant survey (recorded all plant species within the W-shape transect line) along all transects was completed prior to tilling (April 2010). A second and third plant survey was completed along the three passive treatments in June and September 2010. The three surveys were completed to encompass the growing season of spring ephemerals, early summer and late summer plant species. The second and third surveys were not completed on the tilled areas because they were covered in tarpaulin for the duration of the summer. The April and June plant surveys were used to select the plant species that were used in the restoration. This was done through cross-referencing which species the native nursery could grow, what species were known in the area and what species were not present in the restoration areas (to avoid confusion of whether growth was from restoration efforts). The September survey confirmed that the species chosen and grown at the nursery were not present at the restoration locations.

In 2011, three plant surveys (May 19th-28th, June 23rd-26th, August 15th-22nd) were completed on all plots to encompass all potential growing seasons of different plant species. Only the June and August survey were analysed as the May survey contained mostly unknown basal species.

Variables Measured

Abundance and percent cover of each species were recorded at all plots. Percent cover was taken at surveyor's height looking over the plot (approximately 1.3 m above the plot). Total percent cover added to 100% including bare soil, debris, and rocks.

Bird Surveys

Ornithologist Jeffrey Balsdon conducted three bird surveys during the bird breeding seasons of 2010 and 2011. This was done to provide a baseline of birds using habitats in the area for future habitat use comparisons. Bird surveys were conducted for 10 minutes at each of the three fields between 6:45am – 9:30am in 2010 (May 29th, June 13th, and July 1st) and 2011 (May 28th, June 19th, and July 1st) and were based on the protocols outlined in the Atlas of Breeding Birds of Ontario (Cadman et al. 2007).

Data Analysis

Species richness and percent cover were calculated for total number of species, and number of natives (for planted species and not planted native species) and non-native species. Species richness and percent covers were compared using Mann-Whitney *U* test. Data were considered significantly different at $p < 0.05$. Statistica© Version 9.0 (StatSoft 2009) was used for all analyses.

Diversity was measured using Simpson's Index (Magurran 2004). Simpson's Index (D) was used in this paper with the value of 0 representing infinite diversity and 1 representing no diversity. Simpson's Index (D) measures the probability that two individuals randomly selected from the sample will be the same species. This is not to be confused with Simpson's Index of Diversity (1-D) or Simpson's Reciprocal Index (1/D). Simpson's Index (D) was chosen over Shannon Index as the Simpson's Index is less sensitive to missed species and examines diversity more on a dominance scale. The floristic quality index with coefficient of conservatism values was not chosen based on its importance to weighting each species and what would be found in a meadow ecosystem. It was more important in this study to look at richness overall and the sites proportion of natives to non-natives.

The proportion of diversity was calculated as follows:

Simpson's Index: $$D(\text{Simpson}) = \sum \frac{n(n-1)}{N(N-1)}$$

Where n ϵ the abundance of each species, N ϵ total abundance of all species.

Simpson's Index for non-natives: $$D(\text{non-natives}) = \sum \frac{a(a-1)}{N(N-1)}$$

Where a ϵ the abundance of non-native species, N ϵ total abundance of all species.

Proportion of non-natives: $$P = \frac{D(\text{non-natives})}{D(\text{Simpson})}$$

Results

Bird Survey

Fourteen of the birds heard/sighted during the point count during the 2010 and 2011 bird survey are listed as species of concern in Ontario Partners in Flight (2008; Table 3-2). Four of these species, Bobolink, Eastern Meadowlark, Savannah Sparrow and Vesper Sparrow require grassland/agriculture as habitat to survive.

Table 3-2: List of bird species heard or sighted at Boyne Valley Provincial Park Ontario during six point count surveys during the breeding bird seasons of 2010 and 2011. Counts are listed as numbers unless individual bird calls were indistinguishable due to simultaneous/ overlapping calling in which they are listed as 'many' in the table. Bold indicates the species of conservation concern in Ontario Partners in Flight (2008).

	Field 1		Field 2		Field 5		Species of Conservation
Species	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**Concern[a] Habitat**
Alder Flycatcher	0	1	0	0	0	0	N/A
American Crow	10	5	3	2	5	4	N/A
American Goldfinch	2	0	3	2	3	2	N/A
American Kestrel	0	0	1	0	0	0	N/A
American Redstart	0	0	3	1	1	0	N/A
American Robin	1	2	3	4	1	0	N/A
Baltimore Oriole	**1**	**0**	**0**	**0**	**0**	**0**	**Other**
Barn Swallow	**0**	**0**	**0**	**0**	**2**	**3**	**Other**
Black-and-white Warbler	1	0	0	1	0	1	N/A
Belted Kingfisher	**1**	**0**	**1**	**0**	**0**	**0**	**Other**
Black-capped Chickadee	3	0	1	2	1	1	N/A
Black-throated Green Warbler	0	0	2	2	0	0	N/A
Blue Jay	2	3	1	2	1	3	N/A
Bobolink	**many**	**3**	**many**	**0**	**many**	**2**	**Grassland/agriculture**
Brown Thrasher	**0**	**0**	**0**	**0**	**0**	**1**	**Shrub/successional**
Cedar Waxwings	3	3	2+	3	0	0	N/A
Chipping Sparrow	1	2	2	1	4	1	N/A
Common Grackle	0	1	0	0	0	0	N/A
Common Yellowthroat	2	3	1	0	0	0	N/A
Downy Woodpecker	0	1	0	1	0	0	N/A
Eastern Bluebird	0	0	0	0	1	0	N/A
Eastern Meadowlark	**0**	**0**	**0**	**0**	**1**	**1**	**Grassland/agriculture**
Eastern Phoebe	0	0	1	0	0	0	N/A
Eastern Wood-Pewee	**2**	**0**	**1**	**1**	**0**	**0**	**Forest**
Eastern Kingbirds	2	0	0	0	0	1	N/A
European Starling	0	2	0	1	0	0	N/A
Field Sparrow	**0**	**1**	**0**	**0**	**0**	**0**	**Shrub/successional**
Grasshopper Sparrow	0	0	0	0	1	0	N/A
Gray catbird	1	0	0	0	0	0	N/A
Great Blue Heron	0	0	1	0	0	0	N/A
Great-crested Flycatcher	2	1	1	1	0	1	N/A
Herring Gull	0	1	0	0	0	0	N/A
Indigo Bunting	1	1	0	1	2	4	N/A
Magnolia Warbler	0	0	0	2	0	0	N/A
Nashville Warbler	1	0	1	1	0	0	N/A
Northern Flicker	**1**	**1**	**0**	**0**	**1**	**0**	**Forest**
Northern Waterthrush	0	0	0	1	0	0	N/A
Ovenbird	1	2	2	1	0	2	N/A
Pileated Woodpecker	0	0	0	0	0	1	N/A
Red-eyed Vireo	3	1	2	2	2	3	N/A
Red-headed Woodpecker	**0**	**0**	**0**	**0**	**0**	**1**	**Forest**

Species	Field 1		Field 2		Field 5		Species of Conservation Concern[a] Habitat
	2010	2011	2010	2011	2010	2011	
Red-winged Blackbird	many	3	5	0	1	2	N/A
Rose-breasted Grosbeak	**0**	**1**	**1**	**0**	**0**	**0**	**Forest**
Rock Pigeon	0	0	0	0	2	2	N/A
Savannah Sparrow	**2**	**0**	**0**	**2**	**2**	**1**	**Grassland/agriculture**
Song Sparrow	2	5	2	1	1	3	N/A
Veery	0	0	0	1	0	0	N/A
Vesper Sparrow	**0**	**0**	**0**	**0**	**2**	**1**	**Grassland/agriculture**
White-breasted Nuthatch	0	1	0	0	0	0	N/A
Wild Turkey	1	1	0	0	0	0	N/A
Wood Thrush	**0**	**1**	**2**	**3**	**0**	**0**	**Forest**
Woodpecker species	1	1	0	0	0	0	N/A

[a]Listed as special concern by Ontario Landbird Conservation Plan (Ontario Partners in Flight 2008)

Plant Survey - Dominant Species

At the Over 30-year Old Field, the 1-year Fallow field was dominated by *Poa pratensis* and *Bromis inermis* with all other species under 10% of the total abundance (Table 3-3). Tilling the land decreased the dominance of *Poa pratensis and Bromis inermis* allowing other species to dominate. Of the planted species *Elymus trachycaulus* ssp. *trachycaulus* and *Penstemon hirsutus* was one of the dominant species in the treatment areas.

At the 7-years Hay field, the 1-year Fallow field was more evenly distributed in dominance than the tilled areas (Table 3-3). Although not a dominant species, tilling eliminated the presence of native *Sisyrinchium montanum* (blue-eyed grass), which was found in the 1-year Fallow field.

At the Annual Crop Rotation field, tilling and planting increased the richness of species that dominated the area (Table 3-2). One of the dominant species in the 1-year Fallow field was the native ‘undesirable’ species *Conyza canadensis* (Canada fleabane). This was still present after tilling, but not as one of the dominant species. Planted native grass species *Elymus trachycaulus* ssp. *trachycaulus* (slender wheatgrass) was one of the dominant species in the Plugs Only transect.

Table 3-3: Dominant three species or all species greater than 10% for abundance in June and August plant survey at Boyne Valley Provincial Park. Bolded species are native species (planted and not planted).

Field Site	**Dominant Plant Species**	
Over 30-year Old Field	**June Survey**	**August Survey**
1-year-Fallow	*Poa pratensis* (77.4%) *Bromis inermis* (11.5%) ***Solidago canadensis* (4.6%)**	*Poa pratensis* (80.7%) *Bromis inermis* (8.5%) ***Solidago canadensis* (4.9%)**
Control	***Solidago* sp. (20.3%)** *Oxalis corniculata* (20.2%) *Elymus repens* (15.7%)	***Solidago* sp (19.8%)** *Oxalis corniculata* (19.5%) *Elymus repens* (15.7%)
Plugs Only	***Elymus trachycaulus* (21.6%)** *Portulaca oleracea* (16.3%) *Oxalis corniculata* (11.0%)	***Elymus trachycaulus* (19.6%)** *Oxalis corniculata* (13.4%) ***Solidago canadensis* (11.2%)**
Seeds Only	***Solidago canadensis* (20.2%)** *Portulaca oleracea* (14.9%) *Chenopodium alcum* (13.7%) ***Penstemon hirsutus* (11.1%)**	***Solidago canadensis* (20.1%)** *Chenopodium alcum* (14.5%) Basal (12.7%) ***Penstemon hirsutus* (12.4%)** *Poa pratensis* (11.4%)
Plugs and Seeds	*Urtica Dioica* (37.1%) ***Elymus trachycaulus* (9.9%)** Basal (9.5%)	*Urtica Dioica* (27.4%) Basal (12.4%) ***Elymus trachycaulus* (11.7%)**
7-year Hay Field	**June Survey**	**August Survey**
1-year Fallow	*Poa pratensis* (19.6%) *Phleum pratense* (15.5%) *Poa compressa* (13.4%)	*Poa compressa* (14.9%) *Dactylis glomerata* (13.5%) *Poa pratensis* (13.0%) ***Solidago canadensis* (11.5%)** *Pleum pratense* (10.0%)
Control	*Poa compressa* (22.2%) *Plantago major* (11.4%) *Oxalis corniculata* (10.7%) *Portulaca oleracea* (10.0%)	*Phleum pratense* (14.7%) *Poa compressa* (12.9%) *Plantago major* (12.1%) *Oxalis corniculata* (11.5%) Basal (10.8%)

Field Site	**Dominant Plant Species**	
Plugs Only	*Poa compressa* (35.9%) ***Mentha arvensis*** **(9.4%)** Basal (8.7%)	*Poa compressa* (35.1%) ***Mentha arvensis*** **(10.8%)** *Echinochloa crusgalli* (9.0%)
Seeds Only	*Poa compressa* (32.6%) *Poa pratensis* (19.0%) *Plantago major* (11.1%)	*Poa compressa* (40.2%) *Poa pratensis* (9.6%) *Panicum capillare* (8.9%)
Plugs and Seeds	*Poa compressa* (47.4%) *Phleum pretense* (9.1%) *Portulaca oleracea* (8.9%)	*Poa compressa* (28.0%) *Panicum capillare* (16.3%) *Echinochloa crusgalli* (11.3%)
Annual Crop Rotation Field	**June Survey**	**August Survey**
1-year Fallow	*Elymus repens* (37.3%) ***Conyza canadensis*** **(14.8%)** Basal (9.9%)	*Elymus repens* (49.7%) ***Conyza canadensis*** **(16.4%)** Basal (5.4%)
Control	*Polygonum convolvulus* (27.5%) *Panicum capillare* (24.7%) *Oxalis corniculata* (14.4%) *Elymus repens* (12.9%)	*Panicum capillare*(40.3%) *Elymus repens* (17.9%) *Oxalis corniculata* (13.8%) *Polygonum convolvulus* (10.9%)
Plugs Only	*Oxalis corniculata* (17.7%) ***Elymus trachycaulus*** **(13.9%)** *Panicum capillare* (12.4) *Elymus repens* (10.8%)	*Panicum capillare* (21.5%) *Oxalis corniculata* (16.0%) *Elymus repens* (13.2%)
Seeds Only	*Panicum capillare* (36.9%) *Oxalis corniculata* (16.6%) *Polygonum convolvulus* (10.9%)	*Panicum capillare* (44.8%) *Oxalis corniculata* (17.5%) *Polygonum convolvulus* (12.8%)
Plugs and Seeds	*Oxalis corniculata* (19.8%) *Polygonum convolvulus* (16.9%) *Panicum capillare* (11.1%)	*Panicum capillare* (21.5%) *Oxalis corniculata* (15.8%) *Polygonum convolvulus* (12.4%) *Elymus repens* (10.0%)

Simpson's Diversity Index: June and August 2011 Plant Survey

Simpson's Index (D) was calculated for each of the five transects at all three fields with the respective proportion of native and non-native species (Table 3-4).

Table 3-4: Simpson's Index (D) of plant survey at the Over 30-year Old Field, 7-years Hay field and an Annual Crop Rotation field. Each field was divided into transects of 1-year Fallow, Control, Plugs Only, Seeds Only and Plugs and Seeds. Plant surveys were conducted in June and August of 2011 at Boyne Valley Provincial Park, Ontario.

Simpson's Index (D)	June Survey			August Survey		
	D	% Native	% Non-native	D	% Native	% Non-native
Field 1: Over 30-year Old Field						
1-year Fallow	0.62	0.3	99.7	0.66	0.4	99.6
Control	0.13	64.1	33.2	0.12	32.3	64.7
Plugs Only	0.11	59.1	38.8	0.10	65.5	30.9
Seeds Only	0.12[a]	47.0	46.1	0.11[b]	50.7	35.2
Plugs and Seeds	0.18	10.7	84.2	0.13[c]	21.2	66.8
Field 2: 7-years Hay						
1-year Fallow	0.11	2.9	92.6	0.1	14.3	85.3
Control	0.10	0.6	97.1	0.10[d]	1.2	86.7
Plugs Only	0.16	11.1	84.3	0.16	13.3	86.3
Seeds Only	0.17	2.9	93.9	0.2	3.1	96.7
Plugs and Seeds	0.26	2.2	94.8	0.14	8.7	90.0
Field 5: Annual Crop Rotation						
1-year Fallow	0.18	12.0	82.7	0.28	9.5	89.4
Control	0.18	0.1	98.2	0.23	0.3	99.0
Plugs Only	0.10	32.8	67.7	0.11	12.1	86.9
Seeds Only	0.19	2.5	97.1	0.26	1.0	99.0
Plugs and Seeds	0.11	14.0	83.8	0.11	12.1	86.1

Note: all areas with >5% proportion of unknown species are footnoted

[a]7% proportion of unknown species

[b]14% proportion of unknown species

[c]12% proportion of unknown species

[d]12% proportion of unknown species

Simpson's Diversity Index: Fallow versus Tilled areas

Tilling increased the diversity at the Over 30-year Old Field from D (range 0.62 to 0.66) to D (range: 0.10 to 0.18) and increased the proportion of native species from native proportion (0.3% to 0.4%) to native proportion (range 10.7%-65.5%).

Tilling did not change or decreased the diversity at the 7-years Hay field from D (range 0.10 to 0.11) to D (range 0.10 to 0.26) and overall decreased the proportion of native species from native proportion (range 2.9% to 14.3%) to native proportion (range 0.6% to 13.3%). The only proportion of native species that increased after tilling was at the Plugs Only Transect in the June survey (native proportion from 2.9% to 11.1%).

Tilling did not change or increased the diversity at the Annual Crop Rotation field from D (range 0.18 to 0.28) to D (range 0.10 to 0.26) and had mixed results for proportion of native species from native proportion (9.5% to12%) to native proportion (0.1% to 32.8%).

Simpson's Diversity Index: Plugs Only versus Seeds Only versus Plugs and Seeds

The treatment Plugs Only had the highest proportion of natives for both June and August surveys at all three fields. The only exception was at the Annual Crop Rotation field where the Plugs and Seeds transect had the same proportion of natives (12.1%) as Plugs Only during the August survey.

Comparison of Native, Non-Native and Total Number of Species in June and August 2011 Plant Survey

There was a higher number of non-native species than native species in all transects at all three fields (Figure 3-2 to Figure 3-4).

Number of Species: Fallow versus Tilled areas

The fallow transect had the least number of species at the Over 30-year Old Field and the least number of non-native species compared to the tilled transects (Figure 3-2). In June, the fallow transect at the Over 30-year Old Field had a comparable number of native species (not planted) to the tilled transects but was less by August.

The fallow transect had a similar number of species at the 7-years Hay field and an equal or higher number of native species (not planted) compared to the tilled transects (Figure 3-3).

The fallow transect had the highest number of native species (not planted) at the Annual Crop Rotation field compare to the tilled transects (Figure 3-4). There was no pattern for number of non-native species and all species between the fallow transect and the tilled transects.

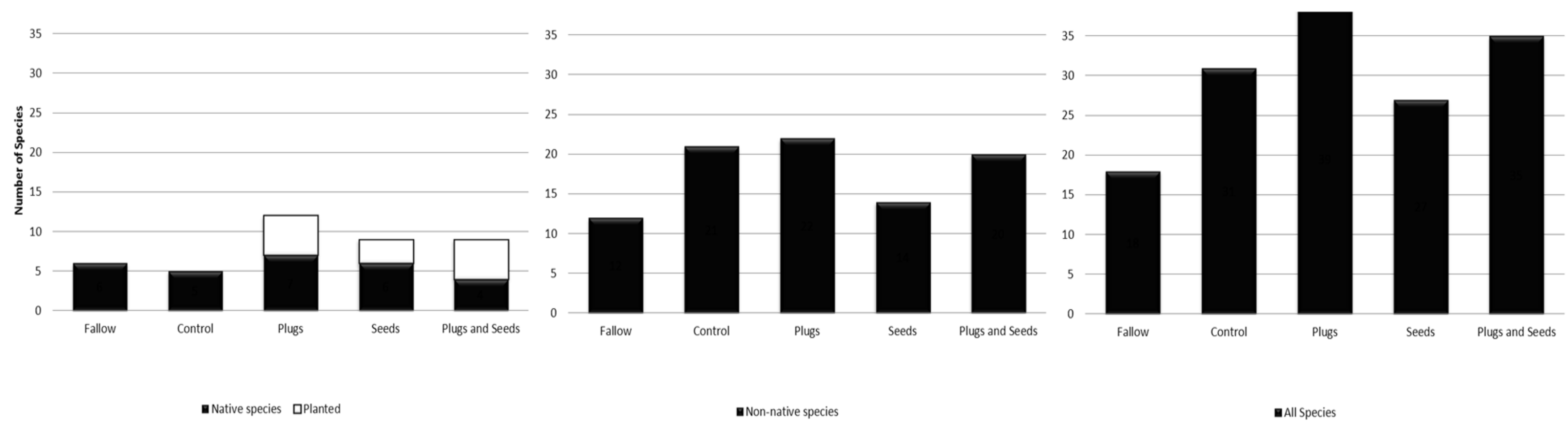
Number of Species: Plugs Only versus Seeds Only versus Plugs and Seeds

The Plugs Only at the Over 30-year Old Field had the highest number of native species (including plantings; Figure 3-2).

The Plugs Only and the Plugs and Seeds at the 7-years Hay field had a similar number of native species (including plantings; Figure 3-3).

The Plugs and Seeds at the Annual Crop Rotation field had the highest number of native species (including plantings; Figure 3-4); however, they had a higher number of native species (not planted) compared to the Plugs Only and Seeds Only transects.

a



b

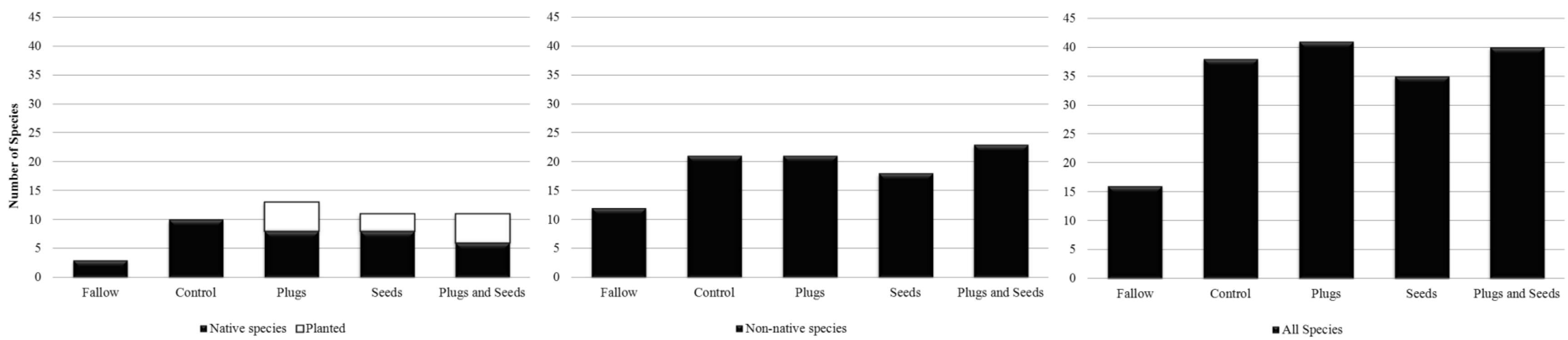
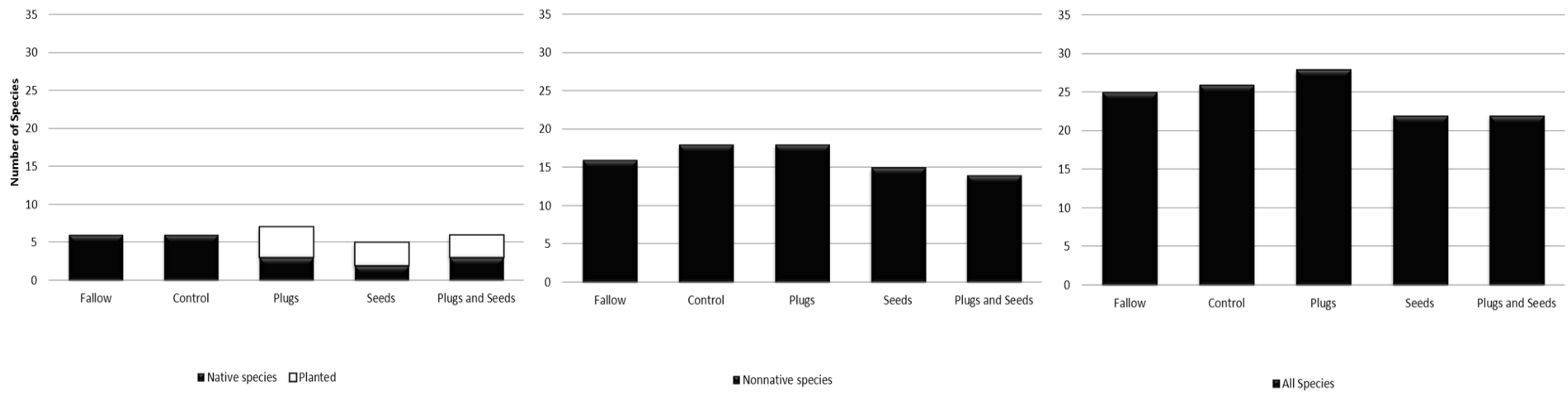


Figure 3-2: Number of native species (including planted), non-native species and all species in Field 1 (Over 30-year Old Field) at five transects: 1. 1-year fallow, 2. Control 3. Plugs Only, 4. Seeds Only, and 5. Plugs and Seeds. The All Species graph includes unknown species. Plant survey was conducted in a) June 2011 and b) August 2011 at Boyne Valley Provincial Park, Ontario.

a



b

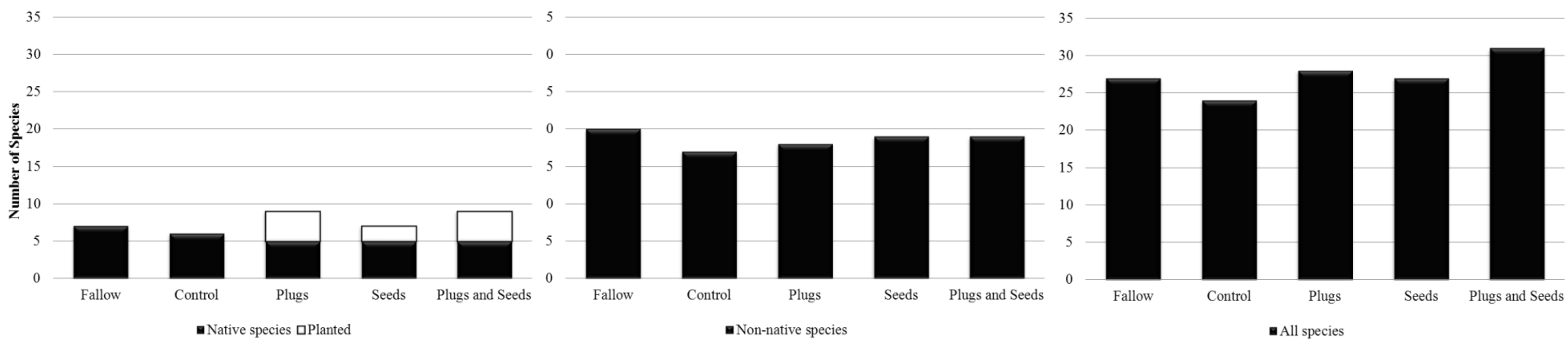
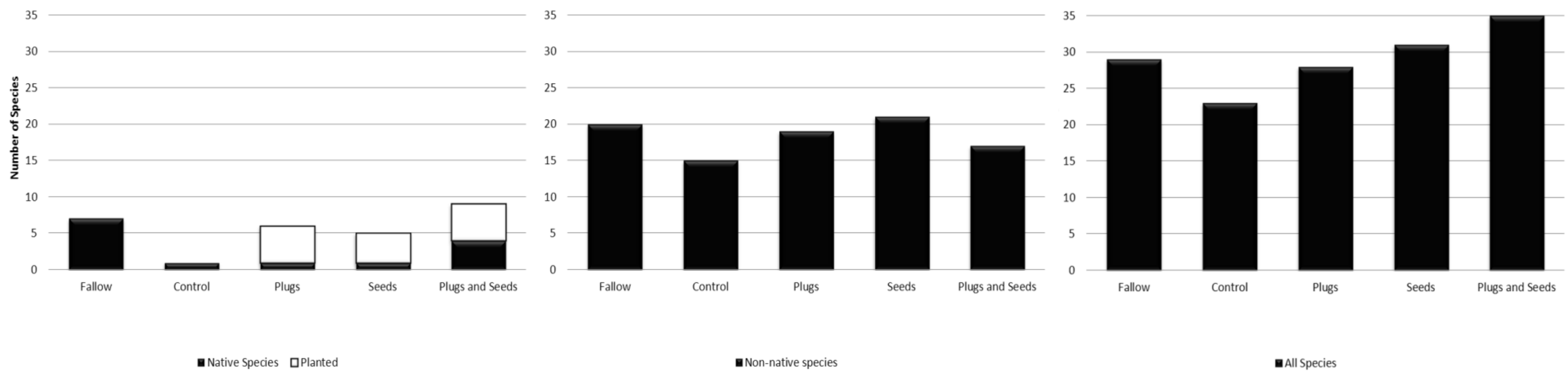


Figure 3-3: Number of native species (including planted), non-native species and all species in Field 2 (7-years Hay) at five transects: 1. 1-year fallow, 2. Control 3. Plugs Only, 4. Seeds Only, and 5. Plugs and Seeds. The All Species graph includes unknown species. Plant survey was conducted in a) June 2011 and b) August 2011 at Boyne Valley Provincial Park, Ontario.

a



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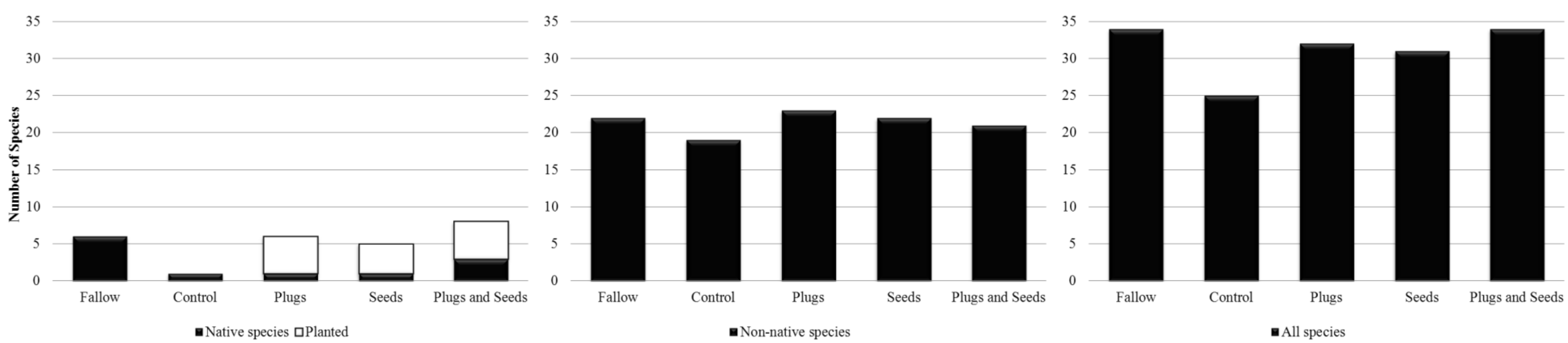


Figure 3-4: Number of native species (including planted), non-native species and all species in Field 5 (Annual Crop Rotation) at five transects: 1. 1-year fallow, 2. Control 3. Plugs Only, 4. Seeds Only, and 5. Plugs and Seeds. The All Species graph includes unknown species. Plant survey was conducted in a) June 2011 and b) August 2011 at Boyne Valley Provincial Park, Ontario.

Percent Cover: Fallow versus Tilled areas

There was no trend in percent cover between fallow and tilled transects at the Over 30-year Old Field (Figure 3-5).

At the 7-years Hay field, the native species (not planted) were higher in the fallow field compared to the tilled transects (Figure 3-6).

At the Annual Crop Rotation field, the native species (not planted) were higher in the fallow field compared to the tilled transects (Figure 3-7).

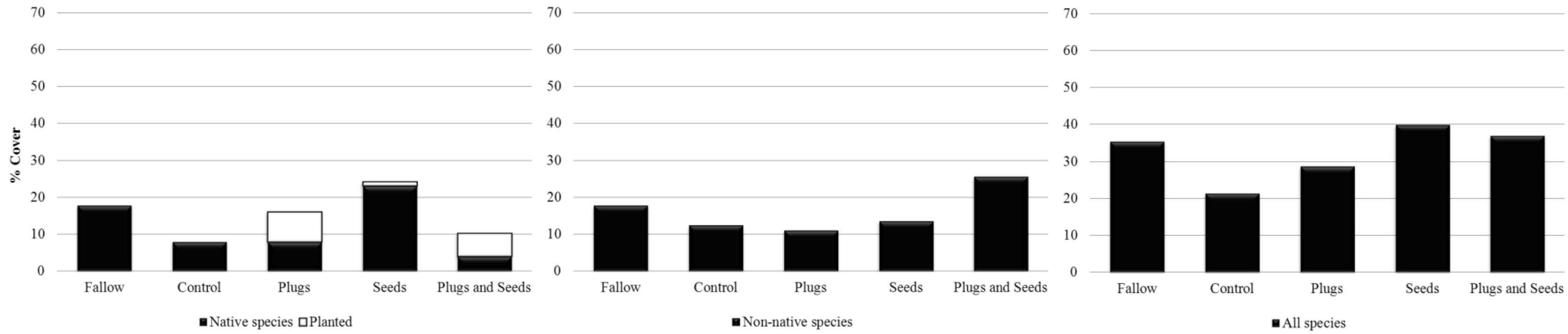
Percent Cover: Plugs Only versus Seeds Only versus Plugs and Seeds

The Plugs Only treatment had the highest percent cover of native species by August at the Over 30-year Old Field (Figure 3-5).

The Plugs Only treatment had the highest percent cover of native species at the 7-years Hay field (Figure 3-6).

The Plugs Only treatment had the highest percent cover of native species mostly contributing from planted species at the Annual Crop Rotation field (Figure 3-7).

a



b

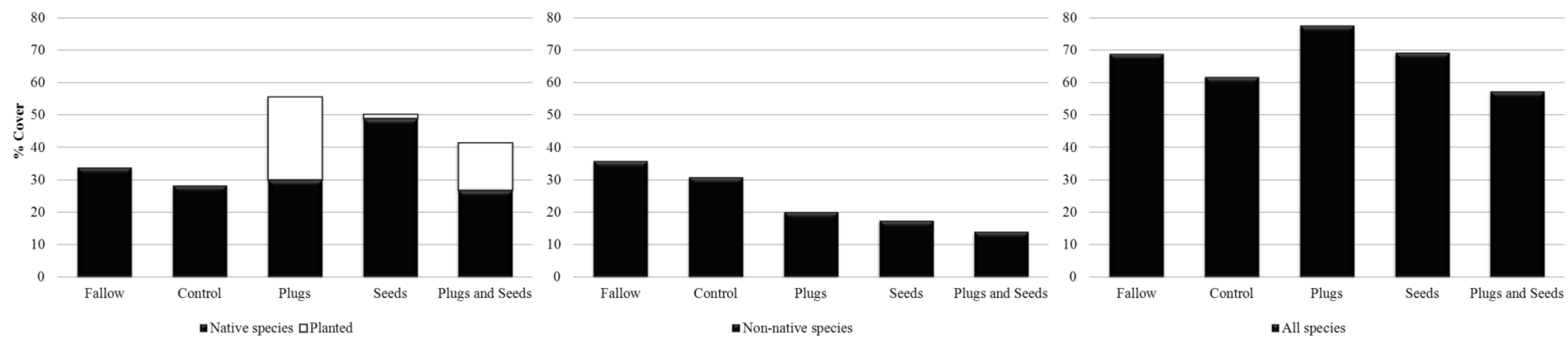


Figure 3-5: Percent cover of native species (including planted), non-native species and all species in Field 1 (Over 30-year Old Field) at five transects: 1. 1-year fallow, 2. Control 3. Plugs Only, 4. Seeds Only, and 5. Plugs and Seeds. The All Species graph includes unknown species. Plant survey was conducted in a) June 2011 and b) August 2011 at Boyne Valley Provincial Park, Ontario.

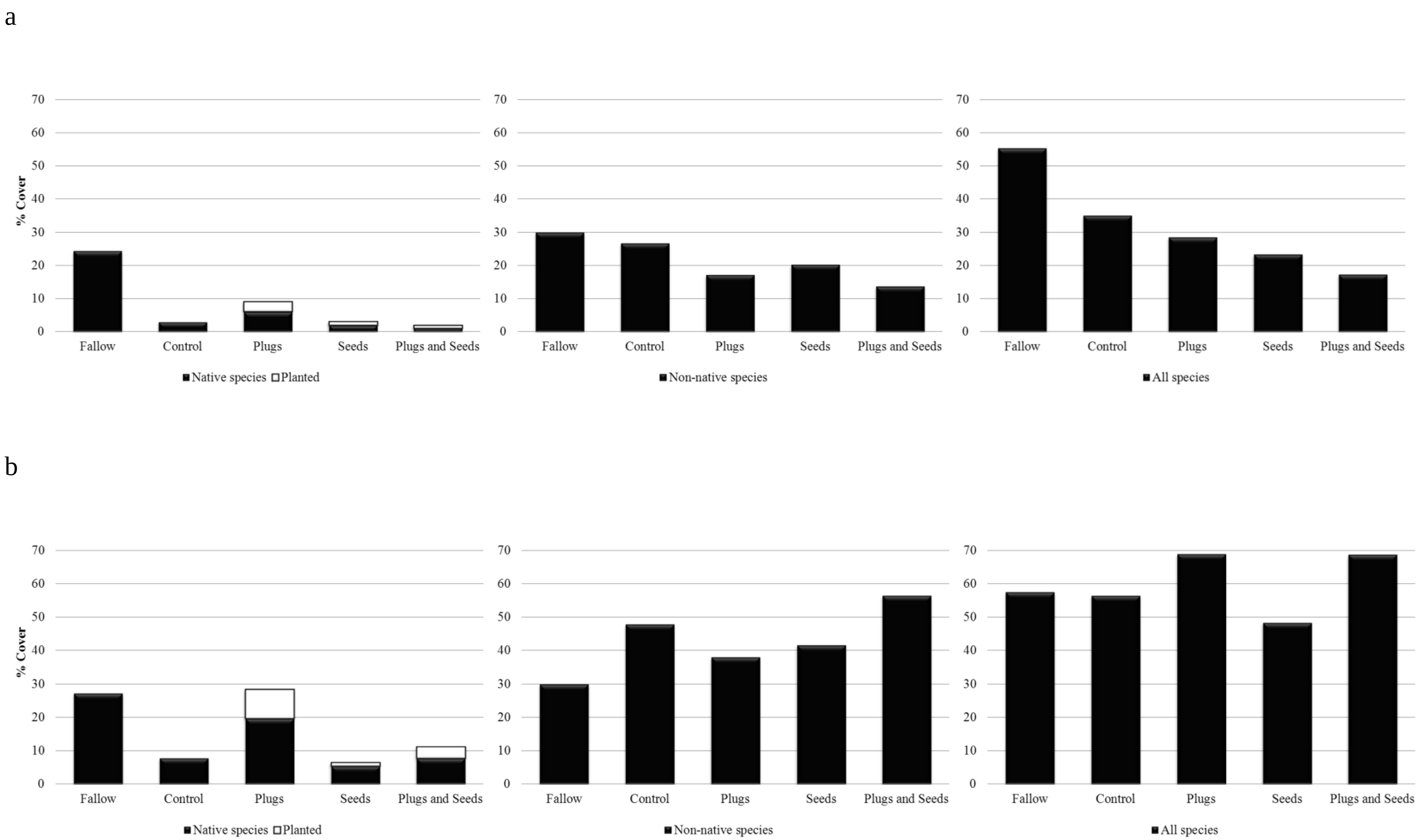
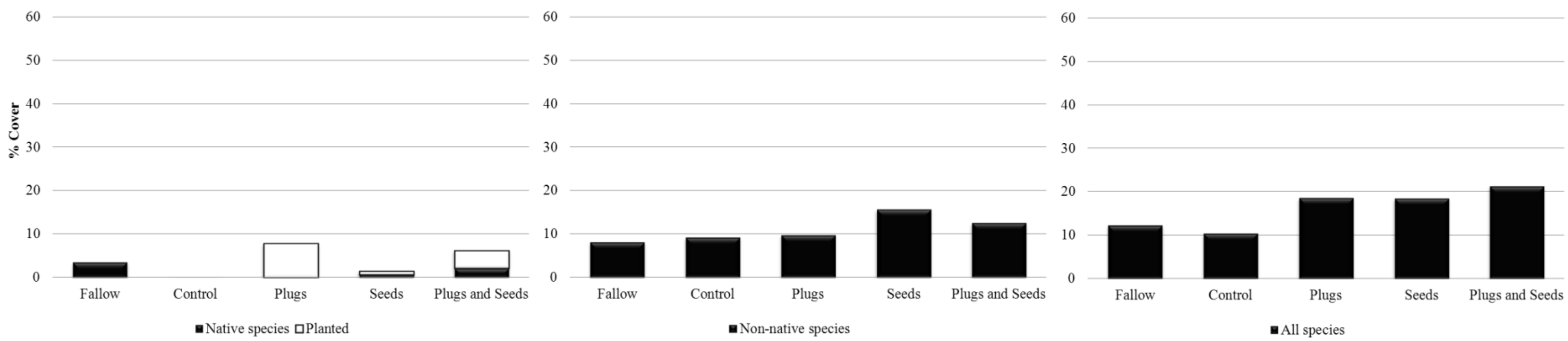


Figure 3-6: Percent cover of native species (including planted), non-native species and all species in Field 2 (7-years Hay) at five transects: 1. 1-year fallow, 2. Control 3. Plugs Only, 4. Seeds Only, and 5. Plugs and Seeds. The All Species graph includes unknown species. Plant survey was conducted in a) June 2011 and b) August 2011 at Boyne Valley Provincial Park, Ontario.

a



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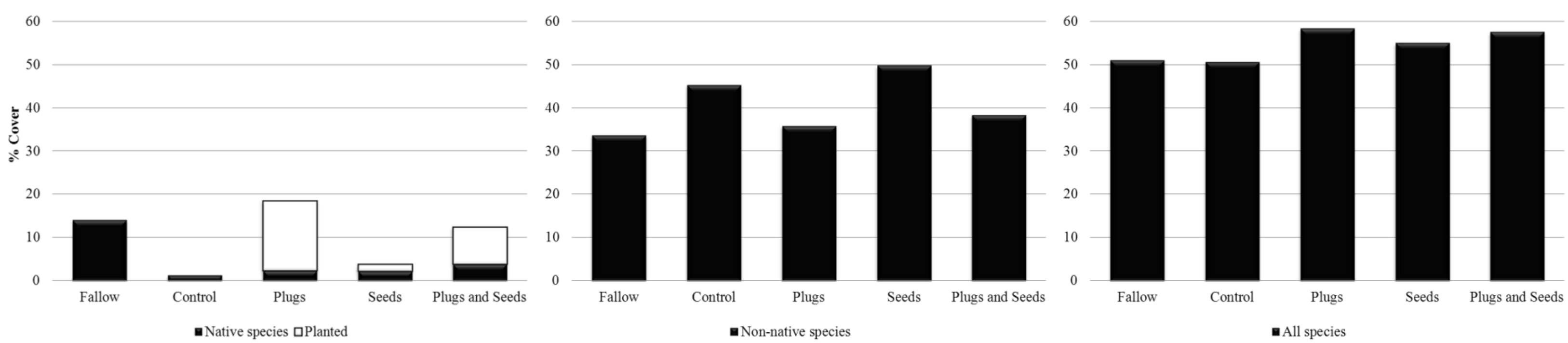

Figure 3-7: Percent cover of native species (including planted), non-native species and all species in Field 5 (Annual Crop Rotation) at five transects: 1. 1-year fallow, 2. Control 3. Plugs Only, 4. Seeds Only, and 5. Plugs and Seeds. The All Species graph includes unknown species. Plant survey was conducted in a) June 2011 and b) August 2011 at Boyne Valley Provincial Park, Ontario.

Mann-Whitney U: Fallow versus Tilled areas

The variables below did not all followed a normal distribution and the non-parametric test Mann-Whitney *U* was chosen to compare between fallow area and tilled areas.

Comparison of species richness (native and non-native) and percent cover (native and non-native) between the fallow area (Fallow) and the different treatments (Control, Plugs Only, Seeds Only, and Plugs and Seeds) of all three fields for both June and August surveys are found in Table 3-5 through 3-12.

Table 3-5: Mann-Whitney *U* results for 1-year Fallow versus the Control (treatment = till only) for June 2011 plant survey at three locations in Boyne Valley Provincial Park, Ontario. Variables include richness (total number of species, number of native species (no plantings), number of non-native species), and percent cover (all plant species, native plant species (not planted), and non-natives plant species). Significance is alpha = 0.05, n = 17 for all transects.

June Survey	Control Median (range)	1-year Fallow Median (range)	*U*	*p-value*
Field 1: Over 30-year Old Field				
Richness (all species)	**9 (7 - 11)**	6 (3 - 11)	32.0	< **0.001**
Richness (native-no plantings)	**2 (1 - 3)**	1 (0 - 1)	80.5	**0.029**
Richness (non-native)	**6 (4 - 9)**	4 (2 - 9)	58.0	**0.003**
Cover all species (%)	15 (10 - 57)	**23 (12 - 71)**	75.0	**0.017**
Cover native (no plantings) (%)	4 (0.5 - 26)	6 (0 - 60)	136.0	0.783
Cover non-native (%)	10 (1 - 37)	**17 (3 - 41)**	70.0	**0.011**
Field 2: 7-years Hay				
Richness (all species)	**12 (4 - 14)**	9 (7 - 13)	85.0	**0.042**
Richness (native-no plantings)	1 (0 - 3)	1 (0 - 3)	138.5	0.850
Richness (non-native)	**9 (1 - 12)**	7 (5 - 9)	85.0	**0.042**
Cover all species (%)	31 (20 - 49)	**50 (33 - 88)**	27.0	<**0.001**
Cover native (no plantings) (%)	2 (0 - 9)	0.5 (0 - 65)	130.5	0.642
Cover non-native (%)	23 (5 - 40)	29.5 (13 - 50)	101.0	0.139
Field 5: Annual Crop Rotation				
Richness (all species)	7 (3 - 15)	**10 (6 - 13)**	31.0	**<0.001**
Richness (native-no plantings)	1 (0 - 1)	1 (0 - 3)	128.0	0.582
Richness (non-native)	**8 (4 - 10)**	5 (3 - 10)	38.5	**<0.001**
Cover all species (%)	**12 (8 - 16)**	11 (6 - 33)	121.0	**0.428**
Cover native (no plantings) (%)	0 (0 - 1)	**2 (0 - 26)**	71.0	**0.012**
Cover non-native (%)	11 (0 - 15)	7 (3 - 30)	90.0	0.063

Note: Bold fonts equal transects that were significantly higher

Table 3-6: Mann-Whitney *U* results for 1-year Fallow land versus Control (treatment = till only) for August 2011 plant survey at three locations in Boyne Valley Provincial Park, Ontario. Variables include richness (total number of species, number of native species (no plantings), number of non-native species), and percent cover (all plant species, native plant species (not planted), and non-natives plant species). Significance is alpha = 0.05, n = 17 for all transects.

August Survey	Control Median (range)	1-year Fallow Median (range)	*U*	*p-value*
Field 1: Over 30-year Old Field				
Richness (all species)	**12 (7 - 17)**	5 (3 - 10)	15.0	<**0.001**
Richness (native-no plantings)	1 (0 - 2)	1 (0 - 3)	140.0	0.890
Richness (non-native)	**7 (4 - 12)**	4 (2 - 8)	35.0	<**0.001**
Cover all species (%)	64 (24 - 87)	71 (44 - 96)	88.0	0.054
Cover native (no plantings) (%)	20 (0 - 50)	25 (0 - 95)	113.5	0.293
Cover non-native (%)	26 (4 - 58)	32 (1 - 92)	124.5	0.502
Field 2: 7-years Hay				
Richness (all species)	11 (6 - 15)	9 (7 - 13)	92.0	0.073
Richness (native-no plantings)	1 (0 - 2)	1 (0 - 4)	100.0	0.130
Richness (non-native)	8 (4 - 11)	7 (6 - 9)	99.0	0.121
Cover all species (%)	55 (38 - 75)	63 (24 - 89)	132.0	0.679
Cover native (no plantings) (%)	3 (0 - 30)	14 (0 - 65)	88.0	0.053
Cover non-native (%)	**46 (31 - 72)**	23 (11 - 79)	52.5	**0.002**
Field 5: Annual Crop Rotation				
Richness (all species)	10 (6 - 16)	9 (3 - 14)	96.5	0.101
Richness (native-no plantings)	1 (0 - 1)	1 (0 - 3)	140.0	0.890
Richness (non-native)	**8 (5 - 13)**	7 (3 - 12)	86.0	**0.046**
Cover all species (%)	52 (31 - 63)	49 (8 - 85)	141.0	0.918
Cover native (no plantings) (%)	1 (0 - 3)	3 (0 - 55)	108.0	0.215
Cover non-native (%)	45 (31 - 60)	16 (2 - 84)	109.0	0.228

Note: Bold fonts equal transects that were significantly higher

Table 3-7: Mann-Whitney *U* results for 1-year Fallow land versus Plugs Only for June 2011 plant survey at three locations in Boyne Valley Provincial Park, Ontario. Variables include richness (total number of species, number of planted plugs, number of native species (no plantings), number of non-native species), and percent cover (all plant species, planted species, native plant species (not planted), and non-natives plant species). Significance is alpha = 0.05, n = 17 for all transects.

June Survey	Plugs Only Median (range)	1-year Fallow Median (range)	*U*	*p-value*
Field 1: Over 30-year Old Field				
Richness (all species)	**12 (10 - 15)**	6 (3 - 11)	5.5	**<0.001**
Richness (planted)	**3 (2 - 4)**	0 (0 - 0)	0.0	**<0.001**
Richness (native-no plantings)	2 (0 - 4)	1 (0 - 1)	99.0	0.121
Richness (non-native)	**6 (3 - 9)**	4 (2 - 9)	86.0	0.046
Cover all species (%)	27 (20 - 47)	23 (12 - 71)	140.5	0.904
Cover planted (%)	**8 (3 - 16)**	0 (0 - 0)	0.0	**<0.001**
Cover native (no plantings) (%)	6 (1 - 27)	6 (0 - 60)	143.0	0.972
Cover non-native (%)	11 (3 - 23)	**17 (3 - 41)**	74.0	**0.016**
Field 2: 7-years Hay				
Richness (all species)	10 (7 - 15)	9 (7 - 13)	91.5	0.071
Richness (planted)	**3 (1 - 4)**	0 (0 - 0)	0.0	**<0.001**
Richness (native-no plantings)	1 (0 - 2)	1 (0 - 3)	138.0	0.836
Richness (non-native)	6 (3 - 9)	7 (5 - 9)	90.5	0.065
Cover all species (%)	26 (16 - 46)	**50 (33 - 88)**	19.5	**<0.001**
Cover planted (%)	**3 (0 - 8)**	0 (0 - 0)	8.5	**<0.001**
Cover native (no plantings) (%)	2 (0 - 28)	0.5 (0 - 65)	130.0	0.630
Cover non-native (%)	16 (7 - 32)	**29.5 (13 - 50)**	53.5	**0.002**
Field 5: Annual Crop Rotation				
Richness (all species)	**15 (11 - 19)**	10 (6 - 13)	9.5	**<0.001**
Richness (planted)	**4 (2 - 5)**	0 (0 - 0)	0.0	**<0.001**
Richness (native-no plantings)	0 (0 - 1)	**1 (0 - 3)**	86.0	**0.046**
Richness (non-native)	**9 (7 - 12)**	5 (3 - 10)	15.0	**<0.001**
Cover all species (%)	**19 (13 - 31)**	11 (6 - 33)	35.5	**<0.001**
Cover planted (%)	**7.5 (3 - 14)**	0 (0 - 0)	0.0	**<0.001**
Cover native (no plantings) (%)	0 (0 - 1)	**2 (0 - 26)**	78.5	**0.024**
Cover non-native (%)	**9.5 (6 - 23)**	7 (3 - 30)	81.0	**0.030**

Note: Bold fonts equal transects that were significantly higher

Table 3-8: Mann-Whitney *U* results for 1-year Fallow versus Plugs Only for August 2011 plant survey at three locations in Boyne Valley Provincial Park, Ontario. Variables include richness (total number of species, number of planted plugs, number of native species (no plantings), number of non-native species), and percent cover (all plant species, planted species, native plant species (not planted), and non-natives plant species). Significance is alpha = 0.05, n = 17 for all transects.

August Survey	Plugs Only Median (range)	1-year Fallow Median (range)	*U*	*p-value*
Field 1: Over 30-year Old Field				
Richness (all species)	**13 (9 - 16)**	5 (3 - 10)	3.0	**<0.001**
Richness (planted)	**3 (2 - 4)**	0 (0 - 0)	0.0	**<0.001**
Richness (native-no plantings)	1 (0 - 2)	1 (0 - 3)	127.5	0.570
Richness (non-native)	6 (2 - 10)	4 (2 - 8)	88.0	0.054
Cover all species (%)	70 (43 - 95)	71 (44 - 96)	144.0	1.000
Cover planted (%)	**27 (5 - 54)**	0 (0 - 0)	0.0	**<0.001**
Cover native (no plantings) (%)	11 (0 - 71)	25 (0 - 95)	124.0	0.491
Cover non-native (%)	18 (0 - 48)	**32 (1 - 92)**	79.0	**0.025**
Field 2: 7-years Hay				
Richness (all species)	**14 (8 - 18)**	9 (7 - 13)	30.5	**<0.001**
Richness (planted)	**3 (1 - 4)**	0 (0 - 0)	0.0	**<0.001**
Richness (native-no plantings)	1 (0 - 3)	1 (0 - 4)	138.0	0.836
Richness (non-native)	7 (4 - 11)	7 (6 - 9)	126.5	0.547
Cover all species (%)	67 (49 - 91)	63 (24 - 89)	92.5	0.076
Cover planted (%)	**7 (0.5 - 26)**	0 (0 - 0)	0.0	**<0.001**
Cover native (no plantings) (%)	6 (0 - 65)	14 (0 - 65)	132.0	0.679
Cover non-native (%)	36 (9 - 68)	23 (11 - 79)	91.5	0.071
Field 5: Annual Crop Rotation				
Richness (all species)	**16 (12 - 21)**	9 (3 - 14)	4.0	**<0.001**
Richness (planted)	**4 (3 - 5)**	0 (0 - 0)	0.0	**<0.001**
Richness (native-no plantings)	1 (0 - 1)	1 (0 - 3)	142.0	0.069
Richness (non-native)	**11 (6 - 13)**	7 (3 - 12)	43.0	**<0.001**
Cover all species (%)	54 (36 - 87)	49 (8 - 85)	114.5	0.310
Cover planted (%)	**14 (4 - 47)**	0 (0 - 0)	0.0	**<0.001**
Cover native (no plantings) (%)	3 (0 - 6)	3 (0 - 55)	121.0	0.428
Cover non-native (%)	34 (21 - 67)	16 (2 - 84)	114.5	0.310

Note: Bold fonts equal transects that were significantly higher

Table 3-9: Mann-Whitney *U* results for 1-year Fallow versus Seeds Only for June 2011 plant survey at three locations in Boyne Valley Provincial Park, Ontario. Variables include richness (total number of species, number of planted plugs, number of native species (no plantings), number of non-native species), and percent cover (all plant species, planted species, native plant species (not planted), and non-natives plant species). Significance is alpha = 0.05, n = 17 for all transects.

June Survey	Seeds Only Median (range)	1-year Fallow Median (range)	*U*	*p-value*
Field 1: Over 30-year Old Field				
Richness (all species)	**9 (6 - 14)**	6 (3 - 11)	27.0	**<0.001**
Richness (planted)	**2 (0 - 3)**	0 (0 - 0)	8.5	**<0.001**
Richness (native-no plantings)	**2 (0 - 3)**	1 (0 - 1)	77.0	**0.021**
Richness (non-native)	**6 (3 - 9)**	4 (2 - 9)	82.5	**0.034**
Cover all species (%)	37 (6 - 82)	23 (12 - 71)	128.5	0.593
Cover planted (%)	**1.5 (0 - 3)**	0 (0 - 0)	42.5	**<0.001**
Cover native (no plantings) (%)	12 (0 - 75)	6 (0 - 60)	112.0	0.270
Cover non-native (%)	9 (2 - 41)	17 (3 - 41)	89.0	0.058
Field 2: 7-years Hay				
Richness (all species)	8 (3 - 11)	9 (7 - 13)	111.5	0.263
Richness (planted)	**1 (0 - 2)**	0 (0 - 0)	25.5	**<0.001**
Richness (native-no plantings)	0 (0 - 1)	**1 (0 - 3)**	64.0	**0.006**
Richness (non-native)	5 (2 - 8)	**7 (5 - 9)**	79.0	**0.025**
Cover all species (%)	23 (4 - 48)	**50 (33 - 88)**	12.5	**<0.001**
Cover planted (%)	0 (0 - 1)	0 (0 - 0)	119.0	0.389
Cover native (no plantings) (%)	0 (0 - 25)	0.5 (0 - 65)	104.0	0.168
Cover non-native (%)	23 (4 - 37)	**29.5 (13 - 50)**	78.5	**0.024**
Field 5: Annual Crop Rotation				
Richness (all species)	**15 (14 - 21)**	10 (6 - 13)	6.5	**<0.001**
Richness (planted)	**3 (2 - 4)**	0 (0 - 0)	0.0	**<0.001**
Richness (native-no plantings)	1 (0 - 1)	1 (0 - 3)	135.0	0.757
Richness (non-native)	**9 (7 - 13)**	5 (3 - 10)	11.5	**<0.001**
Cover all species (%)	**19 (15 - 29)**	11 (6 - 33)	34.0	**<0.001**
Cover planted (%)	**2 (1 - 3)**	0 (0 - 0)	0.00	**<0.001**
Cover native (no plantings) (%)	1 (0 - 2)	2 (0 - 26)	105.0	0.179
Cover non-native (%)	**16 (13 - 22)**	7 (3 - 30)	18.5	**<0.001**

Note: Bold fonts equal transects that were significantly higher

Table 3-10: Mann-Whitney *U* results for 1-year Fallow land versus Seeds Only for August 2011 plant survey at three locations in Boyne Valley Provincial Park, Ontario. Variables include richness (total number of species, number of planted plugs, number of native species (no plantings), number of non-native species), and percent cover (all plant species, planted species, native plant species (not planted), and non-natives plant species). Significance is alpha = 0.05, n = 17 for all transects.

August Survey	Seeds Only Median (range)	1-year Fallow Median (range)	*U*	*p-value*
Field 1: Over 30-year Old Field				
Richness (all species)	**11 (6 - 14)**	5 (3 - 10)	15.5	**<0.001**
Richness (planted)	**1 (0 - 3)**	0 (0 - 0)	51.0	**0.001**
Richness (native-no plantings)	**2 (1 - 4)**	1 (0 - 3)	82.0	**0.032**
Richness (non-native)	5 (3 - 8)	4 (2 - 8)	105.0	0.179
Cover all species (%)	78 (9 - 95)	71 (44 - 96)	133.0	0.705
Cover planted (%)	**1 (0 - 6)**	0 (0 - 0)	59.5	**0.004**
Cover native (no plantings) (%)	40 (1 - 90)	25 (0 - 95)	115.5	0.326
Cover non-native (%)	8 (2 - 68)	**32 (1 - 92)**	81.5	**0.031**
Field 2: 7-years Hay				
Richness (all species)	**12 (8 - 16)**	9 (7 - 13)	63.0	**0.005**
Richness (planted)	**1 (0 - 2)**	0 (0 - 0)	25.5	**<0.001**
Richness (native-no plantings)	1 (0 - 2)	1 (0 - 4)	116.0	0.335
Richness (non-native)	8 (5 - 12)	7 (6 - 9)	99.5	0.125
Cover all species (%)	47 (22 - 75)	63 (24 - 89)	96.0	0.098
Cover planted (%)	**1 (0 - 4)**	0 (0 - 0)	59.5	**0.004**
Cover native (no plantings) (%)	0.5 (0 - 55)	**14 (0 - 65)**	78.0	**0.023**
Cover non-native (%)	**39 (10 - 65)**	23 (11 - 79)	86.5	**0.047**
Field 5: Annual Crop Rotation				
Richness (all species)	**14 (10 - 19)**	9 (3 - 14)	15.5	**<0.001**
Richness (planted)	**3.5 (2 - 4)**	0 (0 - 0)	0.0	**<0.001**
Richness (native-no plantings)	1 (0 - 1)	1 (0 - 3)	126.0	0.732
Richness (non-native)	**8.5 (6 - 13)**	7 (3 - 12)	70.5	**0.019**
Cover all species (%)	54.5 (35 - 86)	49 (8 - 85)	109.0	0.340
Cover planted (%)	**2 (0 - 4)**	0 (0 - 0)	8.5	**<0.001**
Cover native (no plantings) (%)	2.5 (0 - 6)	3 (0 - 55)	113.5	0.428
Cover non-native (%)	47.5 (28.5 - 82)	16 (2 - 84)	90.0	0.101

Note: Bold fonts equal transects that were significantly higher

Table 3-11: Mann-Whitney *U* results for 1-year Fallow versus Plugs and Seeds for June 2011 plant survey at three locations in Boyne Valley Provincial Park, Ontario. Variables include richness (total number of species, number of planted plugs, number of native species (no plantings), number of non-native species), and percent cover (all plant species, planted species, native plant species (not planted), and non-natives plant species). Significance is alpha = 0.05, n = 17 for all transects.

June Survey	Plugs and Seeds Median (range)	1-year Fallow Median (range)	*U*	*p-value*
Field 1: Over 30-year Old Field				
Richness (all species)	**11 (7 - 16)**	6 (3 - 11)	12.5	**<0.001**
Richness (planted)	**4 (3 - 5)**	0 (0 - 0)	0.0	**<0.001**
Richness (native-no plantings)	1 (0 - 2)	1 (0 - 1)	118.0	0.371
Richness (non-native)	5 (2 - 9)	4 (2 - 9)	125.5	0.524
Cover all species (%)	28 (19 - 82)	23 (12 - 71)	130.0	0.630
Cover planted (%)	**6 (3 - 12)**	0 (0 - 0)	0.0	**<0.001**
Cover native (no plantings) (%)	3 (0 - 15)	6 (0 - 60)	105.5	0.185
Cover non-native (%)	14 (2 - 75)	17 (3 - 41)	144.5	1.000
Field 2: 7-years Hay				
Richness (all species)	8 (6 - 12)	9 (7 - 13)	108.5	0.221
Richness (planted)	**2 (0 - 3)**	0 (0 - 0)	8.5	**<0.001**
Richness (native-no plantings)	0 (0 - 1)	**1 (0 - 3)**	82.0	**0.033**
Richness (non-native)	5 (3 - 7)	**7 (5 - 9)**	53.5	**0.002**
Cover all species (%)	15 (10 - 34)	**50 (33 - 88)**	1.5	**<0.001**
Cover planted (%)	**1 (0 - 3)**	0 (0 - 0)	51.0	**0.001**
Cover native (no plantings) (%)	0 (0 - 10)	0.5 (0 - 65)	106.0	0.191
Cover non-native (%)	12 (9 - 28)	**29.5 (13 - 50)**	24.5	**<0.001**
Field 5: Annual Crop Rotation				
Richness (all species)	**17 (12 - 22)**	10 (6 - 13)	3.5	**<0.001**
Richness (planted)	**4 (3 - 5)**	0 (0 - 0)	0.0	**<0.001**
Richness (native-no plantings)	1 (1 - 2)	1 (0 - 3)	114.0	0.301
Richness (non-native)	**9 (5 - 12)**	5 (3 - 10)	17.5	**<0.001**
Cover all species (%)	**21 (16 - 53)**	11 (6 - 33)	32.0	**<0.001**
Cover planted (%)	**4 (3 - 9)**	0 (0 - 0)	0.00	**<0.001**
Cover native (no plantings) (%)	1 (0 - 22)	2 (0 - 26)	131.5	0.667
Cover non-native (%)	**13 (8 - 18)**	7 (3 - 30)	37.0	**<0.001**

Note: Bold fonts equal transects that were significantly higher

Table 3-12: Mann-Whitney *U* results for 1-year Fallow versus Plugs and Seeds for August 2011 plant survey at three locations in Boyne Valley Provincial Park, Ontario. Variables include richness (total number of species, number of planted plugs, number of native species (no plantings), number of non-native species), and percent cover (all plant species, planted species, native plant species (not planted), and non-natives plant species). Significance is alpha = 0.05, n = 17 for all transects.

August Survey	Plugs and Seeds Median (range)	1-year Fallow Median (range)	*U*	*p-value*
Field 1: Over 30-year Old Field				
Richness (all species)	**14 (9 - 19)**	5 (3 - 10)	4.5	**<0.001**
Richness (planted)	**4 (2 - 5)**	0 (0 - 0)	0.0	**<0.001**
Richness (native-no plantings)	1 (0 - 3)	1 (0 - 3)	107.0	0.203
Richness (non-native)	6 (2 - 9)	4 (2 - 8)	102.0	0.148
Cover all species (%)	66 (21 - 89)	71 (44 - 96)	95.0	0.091
Cover planted (%)	**10 (3 - 60)**	0 (0 - 0)	0.0	**<0.001**
Cover native (no plantings) (%)	15 (0 - 80)	25 (0 - 95)	136.0	0.782
Cover non-native (%)	10 (2 - 46)	**32 (1 - 92)**	70.0	**0.011**
Field 2: 7-years Hay				
Richness (all species)	**12 (10 - 17)**	9 (7 - 13)	35.5	**<0.001**
Richness (planted)	**2 (1 - 4)**	0 (0 - 0)	0.0	**<0.001**
Richness (native-no plantings)	1 (0 - 2)	1 (0 - 4)	116.5	0.344
Richness (non-native)	7 (5 - 10)	7 (6 - 9)	115.0	0.318
Cover all species (%)	68 (34 - 94)	63 (24 - 89)	95.5	0.095
Cover planted (%)	**2 (0 - 16)**	0 (0 - 0)	17.0	**<0.001**
Cover native (no plantings) (%)	1 (0 - 65)	**14 (0 - 65)**	86.0	**0.046**
Cover non-native (%)	**57 (25 - 77)**	23 (11 - 79)	45.5	**<0.001**
Field 5: Annual Crop Rotation				
Richness (all species)	**15 (12 - 20)**	9 (3 - 14)	6.0	**<0.001**
Richness (planted)	**4 (2 - 5)**	0 (0 - 0)	0.0	**<0.001**
Richness (native-no plantings)	1 (0 - 2)	1 (0 - 3)	121.0	0.428
Richness (non-native)	**9 (6 - 13)**	7 (3 - 12)	75.0	**0.017**
Cover all species (%)	58 (43 - 73)	49 (8 - 85)	107.5	0.209
Cover planted (%)	**8 (2.5 - 16)**	0 (0 - 0)	0.0	**<0.001**
Cover native (no plantings) (%)	3 (0 - 8)	3 (0 - 55)	134.0	0.731
Cover non-native (%)	41 (29 - 54)	16 (2 - 84)	117.0	0.352

Note: Bold fonts equal transects that were significantly higher

In general, at the old field location, the richness of all species increased in the tilled versus fallow area with no difference in the overall percent cover. Native species richness and their percent cover were increased through plantings. Richness of native species that were not planted was higher in Seeds Only area compared to 1-year Fallow area, in August, but was a difference of 2 to 1 species count. In general, non-native richness was not different in the tilled treatment compared to the fallow area (by August); however, the percent cover of non-natives decreased. The overall percent cover was not different between the 1-year Fallow and tilled areas.

In general, at the 7-year Hay field location, the richness of all species was increased in the tilled areas that had plantings versus the 1-year Fallow area. The percent cover of the tilled areas was significantly lower than the 1-year Fallow area in June but had no difference by August. Native species richness and percent cover were increased through plantings. Non-native richness was not different between treatments and fallow area. The percent cover of non-native species was lower in the tilled areas in June but had a higher percent cover by August than the 1-year Fallow area, except for no difference between the Plugs Only area and 1-year Fallow area.

In general, at the annual crop rotation field, the richness of all species was increased in the tilled areas that had plantings versus the 1-year Fallow area with no difference in the percent cover (by August). Native species richness and their percent cover were increased through plantings. Richness of native species not planted was not different except was lower in Plugs Only area compared to 1-year Fallow area (August) with a difference of 1 to 0 species count. Percent cover of native species richness not planted was varied in the June survey but was not different between 1-year Fallow and tilled treatments by August. All tilled treatment areas was significantly higher in non-native richness than 1-year Fallow area with higher percent cover in June but no difference in percent cover by August. Tables 3-5 to 3-12 are summarized in Table 3-13.

Table 3-13: Summary of significantly increased richness and percent cover of all species, planted species, native (not planted) species and non-native species after tilling the land (Control, Plugs Only, Seeds Only, and Plugs and Seeds) versus 1-year Fallow area at three locations of June and August 2011 plant surveys.

Variable	Survey	History Over 30-year Old Field	History 7-years Hay	History Annual Crop Rotation
Richness (all species)	June	Yes	Only in Control	Yes, Except decreased in Control
	August	Yes	Yes, Except no difference in Control	Yes, Except no difference in Control
Richness (planted)	June August	Yes	Yes	Yes
Richness (native-no plantings)	June	Varied	Varied	No, Except decreased in Plugs Only
	August	Only in Seeds Only	No	No
Richness (non-native)	June	Yes, Except no difference in Plugs and Seeds	Varied	Yes
	August	Only in Control	No	Yes
Cover all species (%)	June	No Except lower in the Control area	No, tilled lowered %	Yes
	August	No	No	No
Cover planted (%)	June August	Yes	Yes	Yes
Cover native (no plantings) (%)	June	No	No	Varied
	August	No	Varied	No
Cover non-native (%)	June	Varied	No, Tilled lowered %	Yes, Except no difference in Control
	August	No difference in Control 1-year Fallow higher than all planted treatments	Yes, Except no difference in Plugs Only	No

Mann-Whitney U: Plugs Only versus Seeds Only versus Plugs and Seeds

Comparison between the different treatments (Plugs Only, Seeds Only and Plugs and Seeds) for both June and August plant surveys is found in Table 3-14 to 3-19.

Table 3-14: Mann-Whitney *U* results for Plugs Only versus Seeds Only for June 2011 plant survey at three locations in Boyne Valley Provincial Park, Ontario. Variables include richness (total number of species, number of planted plugs, number of native species (no plantings), number of non-native species), and percent cover (all plant species, planted species, native plant species (not planted), and non-natives plant species). Significance is alpha = 0.05, n = 17 for all transects.

June Survey	Seeds Only Median (range)	Plugs Only Median (range)	*U*	*p-value*
Field 1: Over 30-year Old Field				
Richness (all species)	9 (6 - 14)	**12 (10 - 15)**	66.0	**0.007**
Richness (planted)	2 (0 - 3)	**3 (2 - 4)**	20.0	**<0.001**
Richness (native-no plantings)	2 (0 - 3)	2 (0 - 4)	126.0	0.535
Richness (non-native)	6 (3 - 9)	6 (3 - 9)	137.0	0.809
Cover all species (%)	37 (6 - 82)	27 (20 - 47)	100.0	0.130
Cover planted (%)	2 (0 - 3)	**8 (3 - 16)**	0.5	**<0.001**
Cover native (no plantings) (%)	**12 (0 - 75)**	6 (1 - 27)	83.0	**0.036**
Cover non-native (%)	9 (2 - 41)	11 (3 - 23)	140.5	0.904
Field 2: 7-years Hay				
Richness (all species)	8 (3 - 11)	**10 (7 - 15)**	68.0	**0.009**
Richness (planted)	1 (0 - 2)	**3 (1 - 4)**	26.0	**<0.001**
Richness (native-no plantings)	0 (0 - 1)	**1 (0 - 2)**	58.0	**0.003**
Richness (non-native)	5 (2 - 8)	6 (3 - 9)	144.5	1.000
Cover all species (%)	23 (4 - 48)	26 (16 - 46)	107.5	0.290
Cover planted (%)	0 (0 - 1)	**3 (0 - 8)**	12.5	**<0.001**
Cover native (no plantings) (%)	0 (0 - 25)	**2 (0 - 28)**	79.0	**0.025**
Cover non-native (%)	23 (4 - 37)	16 (7 - 32)	109.0	0.228
Field 5: Annual Crop Rotation				
Richness (all species)	15 (14 - 21)	15 (11 - 19)	103.0	0.158
Richness (planted)	3 (2 - 4)	**4 (2 - 5)**	68.5	**0.009**
Richness (native-no plantings)	**1 (0 - 1)**	0 (0 - 1)	85.0	**0.042**
Richness (non-native)	9 (7 - 13)	9 (7 - 12)	120.5	0.418
Cover all species (%)	19 (15 - 29)	19 (13 - 31)	135.5	0.770
Cover planted (%)	2 (1 - 3)	**8 (3 - 14)**	0.5	**<0.001**
Cover native (no plantings) (%)	**1 (0 - 2)**	0 (0 - 1)	81.0	**0.030**
Cover non-native (%)	**16 (13 - 22)**	9.5 (6 - 23)	24.5	**<0.001**

Note: Bold fonts equal transects that were significantly higher

Table 3-15: Mann-Whitney *U* results for Plugs Only versus Seeds Only for August 2011 plant survey at three locations in Boyne Valley Provincial Park, Ontario. Variables include richness (total number of species, number of planted plugs, number of native species (no plantings), number of non-native species), and percent cover (all plant species, planted species, native plant species (not planted), and non-natives plant species). Significance is alpha = 0.05, n = 17 for all transects.

August Survey	**Seeds Only Median (range)**	**Plugs Only Median (range)**	***U***	***p-value***
Field 1: Over 30-year Old Field				
Richness (all species)	11 (6 - 14)	**13 (9 - 16)**	71.0	**0.012**
Richness (planted)	1 (0 - 3)	**3 (2 - 4)**	14.0	**<0.001**
Richness (native-no plantings)	2 (1 - 4)	1 (0 - 2)	92.5	0.076
Richness (non-native)	5 (3 - 8)	6 (2 - 10)	116.5	0.344
Cover all species (%)	78 (9 - 95)	70 (43 - 95)	136.0	0.783
Cover planted (%)	1 (0 - 6)	**27 (5 - 54)**	1.0	**<0.001**
Cover native (no plantings) (%)	**40 (1 - 90)**	11 (0 - 71)	87.0	**0.049**
Cover non-native (%)	8 (2 - 68)	18 (0 - 48)	136.5	0.796
Field 2: 7-years Hay				
Richness (all species)	12 (8 - 16)	**14 (8 - 18)**	85.5	**0.044**
Richness (planted)	1 (0 - 2)	**3 (1 - 4)**	14.0	**<0.001**
Richness (native-no plantings)	1 (0 - 2)	1 (0 - 3)	105.5	0.185
Richness (non-native)	8 (5 - 12)	7 (4 - 11)	123.5	0.480
Cover all species (%)	47 (22 - 75)	**67 (49 - 91)**	36.0	**<0.001**
Cover planted (%)	1 (0 - 4)	**7 (0.5 - 26)**	21.5	**<0.001**
Cover native (no plantings) (%)	0.5 (0 - 55)	**6 (0 - 65)**	72.5	**0.014**
Cover non-native (%)	39 (10 - 65)	36 (9 - 68)	131.0	0.654
Field 5: Annual Crop Rotation				
Richness (all species)	14 (10 - 19)	**16 (12 - 21)**	62.5	**0.009**
Richness (planted)	4 (2 - 4)	**4 (3 - 5)**	79.0	**0.042**
Richness (native-no plantings)	1 (0 - 1)	1 (0 - 1)	121.0	0.601
Richness (non-native)	9 (6 - 13)	**11 (6 - 13)**	76.0	**0.032**
Cover all species (%)	54.5 (35 - 86)	54 (36 - 87)	130.5	0.857
Cover planted (%)	2 (0 - 4)	**14 (4 - 47)**	0.5	**<0.001**
Cover native (no plantings) (%)	2.5 (0 - 6)	3 (0 - 6)	135.5	1.000
Cover non-native (%)	**48 (29 - 82)**	34 (21 - 67)	48.5	**0.002**

Note: Bold fonts equal transects that were significantly higher

Table 3-16: Mann-Whitney *U* results for till and Plugs and Seeds versus Seeds Only for June 2011 plant survey at three locations in Boyne Valley Provincial Park, Ontario. Variables include richness (total number of species, number of planted plugs, number of native species (no plantings), number of non-native species), and percent cover (all plant species, planted species, native plant species (not planted), and non-natives plant species). Significance is alpha = 0.05, n = 17 for all transects.

June Survey	Plugs and Seeds Median (range)	Plugs Only Median (range)	*U*	*p-value*
Field 1: Over 30-year Old Field				
Richness (all species)	11 (7 - 16)	12 (10 - 15)	120.5	0.809
Richness (planted)	**4 (3 - 5)**	3 (2 - 4)	78.0	**0.023**
Richness (native-no plantings)	1 (0 - 2)	**2 (0 - 4)**	71.5	**0.013**
Richness (non-native)	5 (2 - 9)	6 (3 - 9)	115.5	0.326
Cover all species (%)	28 (19 - 82)	27 (20 - 47)	133.5	0.718
Cover planted (%)	6 (3 - 12)	8 (3 - 16)	98.0	0.113
Cover native (no plantings) (%)	3 (0 - 15)	6 (1 - 27)	91.5	0.071
Cover non-native (%)	14 (2 - 75)	11 (3 - 23)	108.5	0.221
Field 2: 7-years Hay				
Richness (all species)	8 (6 - 12)	**10 (7 - 15)**	66.0	**0.007**
Richness (planted)	2 (0 - 3)	**3 (1 - 4)**	74.0	**0.016**
Richness (native-no plantings)	0 (0 - 1)	**1 (0 - 2)**	77.5	**0.022**
Richness (non-native)	5 (3 - 7)	6 (3 - 9)	110.5	0.249
Cover all species (%)	15 (10 - 34)	**26 (16 - 46)**	47.0	**<0.001**
Cover planted (%)	1 (0 - 3)	**3 (0 - 8)**	65.0	**0.007**
Cover native (no plantings) (%)	0 (0 - 10)	**2 (0 - 28)**	76.0	**0.019**
Cover non-native (%)	12 (9 - 28)	**16 (7 - 32)**	86.0	**0.046**
Field 5: Annual Crop Rotation				
Richness (all species)	**17 (12 - 22)**	15 (11 - 19)	71.5	**0.013**
Richness (planted)	4 (3 - 5)	4 (2 - 5)	127.0	0.558
Richness (native-no plantings)	**1 (1 - 2)**	0 (0 - 1)	40.0	**<0.001**
Richness (non-native)	9 (5 - 12)	9 (7 - 12)	133.0	0.705
Cover all species (%)	21 (16 - 53)	19 (13 - 31)	106.0	0.191
Cover planted (%)	4 (3 - 9)	**8 (3 - 14)**	60.5	**0.004**
Cover native (no plantings) (%)	**1 (0 - 22)**	0 (0 - 1)	55.5	**0.002**
Cover non-native (%)	**13 (8 - 18)**	9.5 (6 - 23)	72.0	**0.013**

Note: Bold fonts equal transects that were significantly higher

Table 3-17: Mann-Whitney *U* results for treatments Plugs and Seeds versus Seeds Only for August 2011 plant survey at three locations in Boyne Valley Provincial Park, Ontario. Variables include richness (total number of species, number of planted plugs, number of native species (no plantings), number of non-native species), and percent cover (all plant species, planted species, native plant species (not planted), and non-natives plant species). Significance is alpha = 0.05, n = 17 for all transects.

August Survey	Plugs and Seeds Median (range)	Plugs Only Median (range)	*U*	*p-value*
Field 1: Over 30-year Old Field				
Richness (all species)	14 (9 to 19)	13 (9 to 16)	134.0	0.731
Richness (planted)	4 (2 to 5)	3 (2 to 4)	90.5	0.065
Richness (native-no plantings)	1 (0 to 3)	1 (0 to 2)	121.0	0.428
Richness (non-native)	6 (2 to 9)	6 (2 to 10)	131.5	0.667
Cover all species (%)	66 (21 to 89)	70 (43 to 95)	100.0	0.130
Cover planted (%)	10 (3 to 60)	**27 (5 to 54)**	73.5	**0.015**
Cover native (no plantings) (%)	15 (0 to 80)	11 (0 to 71)	124.0	0.491
Cover non-native (%)	10 (2 to 46)	18 (0 to 48)	132.5	0.692
Field 2: 7-years Hay				
Richness (all species)	12 (10 to 17)	14 (8 to 18)	98.0	0.113
Richness (planted)	2 (1 to 4)	3 (1 to 4)	103.0	0.158
Richness (native-no plantings)	1 (0 to 2)	1 (0 to 3)	107.5	0.209
Richness (non-native)	7 (5 to 10)	7 (4 to 11)	115.0	0.318
Cover all species (%)	68 (34 to 94)	67 (49 to 91)	143.5	0.986
Cover planted (%)	2 (0 to 16)	**7 (0.5 to 26)**	65.5	**0.007**
Cover native (no plantings) (%)	1 (0 to 65)	**6 (0 to 65)**	78.5	**0.024**
Cover non-native (%)	**57 (25 to 77)**	36 (9 to 68)	53.5	**0.002**
Field 5: Annual Crop Rotation				
Richness (all species)	15 (12 to 20)	16 (12 to 21)	108.0	0.215
Richness (planted)	4 (2 to 5)	4 (3 to 5)	142.0	0.945
Richness (native-no plantings)	1 (0 to 2)	1 (0 to 1)	112.5	0.278
Richness (non-native)	9 (6 to 13)	**11 (6 to 13)**	87.0	**0.049**
Cover all species (%)	58 (43 to 73)	54 (36 to 87)	137.5	0.823
Cover planted (%)	8 (2.5 to 16)	**14 (4 to 47)**	73.5	**0.015**
Cover native (no plantings) (%)	3 (0 to 8)	3 (0 to 6)	108.0	0.215
Cover non-native (%)	41 (29 to 54)	34 (21 to 67)	96.0	0.098

Note: Bold fonts equal transects that were significantly higher

Table 3-18: Mann-Whitney *U* results for Plugs and Seeds versus Seeds Only for June 2011 plant survey at three locations in Boyne Valley Provincial Park, Ontario. Variables include richness (total number of species, number of planted plugs, number of native species (no plantings), number of non-native species), and percent cover (all plant species, planted species, native plant species (not planted), and non-natives plant species). Significance is alpha = 0.05, n = 17 for all transects.

June Survey	Seeds Only Median (range)	Plugs and Seeds Median (range)	*U*	*p-value*
Field 1: Over 30-year Old Field				
Richness (all species)	9 (6 - 14)	11 (7 - 16)	95.0	0.091
Richness (planted)	2 (0 - 3)	**4 (3 - 5)**	4.0	**<0.001**
Richness (native-no plantings)	**2 (0 - 3)**	1 (0 - 2)	46.0	**<0.001**
Richness (non-native)	6 (3 - 9)	5 (2 - 9)	113.5	0.293
Cover all species (%)	37 (6 - 82)	28 (19 - 82)	133.5	0.718
Cover planted (%)	1.5 (0 - 3)	**6 (3 - 12)**	2.0	**<0.001**
Cover native (no plantings) (%)	**12 (0 - 75)**	3 (0 - 15)	47.0	**<0.001**
Cover non-native (%)	9 (2 - 41)	14 (2 - 75)	105.5	0.185
Field 2: 7-years Hay				
Richness (all species)	8 (3 - 11)	8 (6 - 12)	139.5	0.877
Richness (planted)	1 (0 - 2)	**2 (0 - 3)**	75.5	**0.018**
Richness (native-no plantings)	0 (0 - 1)	0 (0 - 1)	119.0	0.389
Richness (non-native)	5 (2 - 8)	5 (3 - 7)	107.0	0.203
Cover all species (%)	23 (4 - 48)	15 (10 - 34)	100.0	0.130
Cover planted (%)	0 (0 - 1)	**1 (0 - 3)**	64.0	**0.006**
Cover native (no plantings) (%)	0 (0 - 25)	0 (0 - 10)	140.0	0.890
Cover non-native (%)	23 (4 - 37)	12 (9 - 28)	89.5	0.060
Field 5: Annual Crop Rotation				
Richness (all species)	15 (14 - 21)	17 (12 - 22)	100	0.130
Richness (planted)	3 (2 - 4)	**4 (3 - 5)**	44.0	**0.001**
Richness (native-no plantings)	1 (0 - 1)	1 (1 - 2)	96.0	0.098
Richness (non-native)	9 (7 - 13)	9 (5 - 12)	132.0	0.679
Cover all species (%)	19 (15 - 29)	21 (16 - 53)	106.0	0.191
Cover planted (%)	2 (1 - 3)	**4 (3 - 9)**	2.0	**<0.001**
Cover native (no plantings) (%)	1 (0 - 2)	1 (0 - 22)	99.5	0.125
Cover non-native (%)	**16 (13 - 22)**	13 (8 - 18)	59.5	**0.004**

Note: Bold fonts equal transects that were significantly higher

Table 3-19: Mann-Whitney *U* results for Plugs and Seeds versus Seeds Only for August 2011 plant survey at three locations in Boyne Valley Provincial Park, Ontario. Variables include richness (total number of species, number of planted plugs, number of native species (no plantings), number of non-native species), and percent cover (all plant species, planted species, native plant species (not planted), and non-natives plant species). Significance is alpha = 0.05, n = 17 for all transects.

August Survey	**Seeds Only Median (range)**	**Plugs and Seeds Median (range)**	***U***	***p-value***
Field 1: Over 30-year Old Field				
Richness (all species)	11 (6 - 14)	**14 (9 - 19)**	68.0	**0.009**
Richness (planted)	1 (0 - 3)	**4 (2 - 5)**	10.5	**<0.001**
Richness (native-no plantings)	2 (1 - 4)	1 (0 - 3)	113.5	0.293
Richness (non-native)	5 (3 - 8)	6 (2 - 9)	132.0	0.679
Cover all species (%)	78 (9 - 95)	66 (21 - 89)	95.0	0.091
Cover planted (%)	1 (0 - 6)	**10 (3 - 60)**	5.5	**<0.001**
Cover native (no plantings) (%)	40 (1 - 90)	15 (0 - 80)	104.5	0.174
Cover non-native (%)	8 (2 - 68)	10 (2 - 46)	144.0	1.000
Field 2: 7-years Hay				
Richness (all species)	12 (8 - 16)	12 (10 - 17)	124.0	0.491
Richness (planted)	1 (0 - 2)	**2 (1 - 4)**	37.0	**<0.001**
Richness (native-no plantings)	1 (0 - 2)	1 (0 - 2)	144.0	1.000
Richness (non-native)	**8 (5 - 12)**	7 (5 - 10)	83.5	**0.037**
Cover all species (%)	47 (22 - 75)	**68 (34 - 94)**	47.5	**<0.001**
Cover planted (%)	1 (0 - 4)	**2 (0 - 16)**	75.0	**0.017**
Cover native (no plantings) (%)	0.5 (0 - 55)	1 (0 - 65)	141.0	0.918
Cover non-native (%)	39 (10 - 65)	**57 (25 - 77)**	66.0	**0.007**
Field 5: Annual Crop Rotation				
Richness (all species)	14 (10 - 19)	15 (12 - 20)	86.0	0.075
Richness (planted)	3.5 (2 - 4)	**4 (2 - 5)**	73.0	**0.024**
Richness (native-no plantings)	1 (0 - 1)	1 (0 - 2)	120.0	0.577
Richness (non-native)	8.5 (6 - 13)	9 (6 - 13)	130.0	0.843
Cover all species (%)	54.5 (35 - 86)	58 (43 - 73)	125.0	0.705
Cover planted (%)	2 (0 - 4)	**8 (3 - 16)**	7.0	**<0.001**
Cover native (no plantings) (%)	2.5 (0 - 6)	3 (0 - 8)	101.0	0.214
Cover non-native (%)	**48 (29 - 82)**	41 (29 - 54)	56.5	**0.004**

Note: Bold fonts equal transects that were significantly higher

Overall at all three locations, richness of planted species increased the most with the Plugs Only and Plugs and Seeds methods. Seeds Only had the lowest richness. Percent cover of planted species was highest with Plugs Only, then Plugs and Seeds and lowest with Seeds Only.

At the Over 30-year Old Field, total richness was lowest at the Seeds Only, with no difference among treatments for richness of natives not planted and non-native species. Percent cover was not different among treatments for overall cover and percent cover of non-native species. The percent cover for native species not planted was not different except that the Seeds Only was higher than Plugs Only area.

At the 7-years Hay field, total richness was highest at the Plugs Only area in June and it was only higher than Seeds Only area by August. Generally, there was no difference of richness for natives not planted and non-native species. Total percent cover was lowest in the Seeds Only treatment. The Plugs Only treatment had the highest percent coverage of the planted species and with natives that were not planted. The Plugs and Seeds treatment had the highest percent cover for non-natives by August survey.

At the Annual Crop Rotation field, overall richness varied among the different treatments. The percent cover of natives were equal (by August) with the non-native richness cover highest in the Plugs Only treatment (by August). The total percent cover was not different between treatments. Percent cover of natives not planted was not different between treatments. The percent cover of non-natives was highest in the Seeds Only treatment. Summary of Table 3-14 to 3-19 is found in Table 3-20.

Table 3-20: Summary of recommendation from Table 3-14 to 3-19 comparing treatments (Plugs Only, Seeds Only, and Plugs and Seeds) at three locations in Boyne Valley Provincial Park, Ontario.

Variable	Survey	History Over 30-year Old Field	History 7-years Hay	History Annual Crop Rotation
Richness (all species)	June	No difference Except Plugs Only higher than Seeds Only	Plugs Only highest	Plugs and Seeds higher than Plugs Only
	August	Seeds Only lowest	Plugs Only higher than Seeds Only	Plugs Only higher than Seeds Only
Richness (planted)	June	Plugs and Seeds highest	Plugs Only highest, then Plugs and Seeds, then Seeds Only	Seeds Only lowest
	August	Seeds Only lowest	Seeds Only lowest	Seeds Only lowest
Richness (native-no plantings)	June	Plugs and Seeds lowest	Plugs Only highest	Plugs Only lowest
	August	No difference	No difference	No difference
Richness (non-native)	June	No difference	No difference	No difference
	August	No difference	Seeds Only higher than Plugs and Seeds	Plugs Only highest
Cover all species (%)	June	No difference	Plugs Only higher than Plugs and Seeds	No difference
	August	No difference	Seeds Only lowest	No difference
Cover planted (%)	June	Seeds Only lowest	Plugs Only highest, then Plugs and Seeds, then Seeds Only	Plugs Only highest, then Plugs and Seeds, then Seeds Only
	August	Plugs Only highest, then Plugs and Seeds, then Seeds Only	Plugs Only highest, then Plugs and Seeds, then Seeds Only	Plugs Only highest, then Plugs and Seeds, then Seeds Only
Cover native (no plantings) (%)	June	Seeds Only highest	Plugs Only highest	Plugs Only lowest
	August	No difference Except Seeds Only higher than Plugs Only	Plugs Only highest	No difference
Cover non-native (%)	June	No difference	Plugs Only higher than Plugs and Seeds	Seeds Only, then Plugs and Seeds, then Plugs Only
	August	No difference	Plugs and Seeds highest	Seeds Only highest

Discussion

Restoration was successful and increased native richness in the experimental fields. The addition of plantings was beneficial for all fields to add native species that would not likely otherwise disperse to the area. Planting a combination of Plugs and Seeds is recommended for all three fields types; however, tilling is only recommended for the Over 30-year Old Field. Both the Plugs Only and Plugs and Seeds treatments had similar results; however, using both Plugs and Seeds over plugs alone will be less expensive and less labour intensive when planting. Therefore, a combination of Plugs and Seeds is considered the most effective method for restoration.

Plant Survey

Restoration efforts are necessary in Boyne Valley Provincial Park if Ontario Parks does not want the leased areas to become dominated with non-native species. The results show that tilling and planting plugs decreases the proportion of non-natives at the Over 30-year Old Field whereas if left abandoned, the 1-year Fallow area was populated with mostly non-natives and weedy species. With mostly no difference between the treatment types in terms of richness and percent cover, and Plugs Only treatment providing the highest proportion of natives, a combination of plugs and seeds after tilling was chosen. This provides a higher percent cover of planted species and is more cost-effective though spread of seed. Similarly, for the 7-year Hay field and the Annual Crop Rotation, the comparison of treatment types suggests that Plugs Only or a combination of Plugs and Seeds is beneficial; however, using seeds is more cost effective and less labour intensive and the combined treatment of Plugs and Seeds was chosen.

In terms of species diversity, native species richness and percent cover, tilling before planting is not recommended in the 7-year Hay field and the Annual Crop Rotation field for different reasons. The hay field contained several desirable native meadow species (for example *Sisyrinchium montanum*) which did not grow the year after tilling or the second year after (Balsdon, personal observation). In accordance with not tilling, Blatt et al. (2005) found that tilling the land on an abandoned hay fields had a lesser degree of influence on succession than soil moisture. At the annual crop rotation, without native species in the seedbank, tilling only changed the dominant species from *Elymus repens* to another non-native species *Panicum capillare*. Tilling may have other benefits not tested in this study such as eradicating dominant species (Smith 2006; Daigle and Havinga 1996), which may create a better planting ground for the planted species. Although tilling changed the species composition, the percent cover was similar between the tilled area and fallow area indicating that a different species will take its place.

One explanation that tilling the land increase native species richness and diversity for the Over 30-year Old Field and not the other two fields, was that the soil was not as degraded as more recently farmed fields. The plots contained natives such as *Erythronium americanum* (trout lily), a forest understory spring ephemeral that was present in several plots the year after tilling and the second year after restoration efforts, *Rhus typhina* (staghorn sumac) shrubs were noted (Balsdon, personal observation).

Spring versus fall tillage can lead to different weed communities dominating (Smith 2006). Spring tillage leads to weed communities being dominated by early emerging spring annuals forbs and C4 grass while fall tillage led to communities being dominated by later-emerging forbs and C3 grasses (Smith 2006). However, tillage does not always work as clonal species can withstand plowing and continue to persist in the soil (Beckwith 1954; Bakken et al. 2009; Brandsaeter et al. 2011) and can dominate old fields (Myster and Pickett 1990). For example deep ploughing (25 cm) can reduce *Circium arvense* (Canada thistle) greater than shallow plouging (12 cm; Brandsaeter et al. 2011; Thomsen et al. 2011). For this reason, I laid tarpaulin throughout the growing season to smother clonal species leaving the soil 'prepared' with less competition for the new plantings (Daigle and Havinga 1996). Laying of tarpaulin was not effective at getting rid of the clonal species in this experiment. At each of the experimental fields, the dominant species in all the 1-year Fallow treatments were grasses (for example *Poa pratensis* and *Elymus repens*) and continued to persist in the tilled and tarped treatments. Non-native species in disturbed areas are frequently short-lived and disappear in successional years; however, the persistent non-natives are problematic for succession (Meiners et al. 2007). All three fields contained persistent non-natives as determined by Ontario Ministry of Natural Resources (2013) (for example *Poa compressa* and *Elymus repens*) with few native species, which suggests that in the future trajectory of these fields will become 'old-fields' without continued intervention. Old fields are typically populated with non-natives weedy species (Daigle and Havinga 1996) with succession arrested (Cramer et al. 2008). Ecologically, these are not beneficial to the resilience of the surrounding landscape and the space could be used to restore native vegetation. For example, within Boyne Valley Provincial Park, meadow ecosystems are lacking from the landscape. In time, forested areas will be removed (from fire, windthrow, or disease) and, if lacking the successional stage between bare soil and forest, these areas will likely become populated with species from the nearby old-field resulting in spread of old-field habitat. Economically and operationally, the farmers are the worried about the weeds from abandoned agriculture fields affecting their neighbouring active agriculture field and would like Ontario Parks to have a restoration management plan in place before retiring the field (per comm. Gordon Brown).

Succession at Boyne Valley Provincial Park Restoration Site

Old fields result frequently from a successional path from land abandonment (Cramer et al. 2008). In restoring the soon to be retired agriculture fields at Boyne Valley Provincial Park, the successional pathway towards an old-field requires manipulation towards a meadow ecosystem. Different mechanisms such as initial site conditions at abandonment time (Meiners et al. 2007), previous crop types (Vengris 1953), dispersal (Primack and Miao 1992; Tilman 1997; Bischoff 2002; Meiners et al. 2007), the persistence of species like *Phleum pratense* that should be autogenically eliminated if it were not for their allelopathic pollen (Murphy 2001, Murphy and Aarssen 1989, Murphy 2000), tilling history (Cromar et al. 1999), and grazing pressures (Crowder et al. 2007) may affect succession within a restoration site. Understanding these factors is essential to directing the succession of a restoration project.

Site history has been shown to have an effect on the first few years of restoration as it controls early successional species (Meiners et al. 2007); however, convergence of old-fields is known to occur approximately 8 to 10 years after abandonment (Beckwith 1954; Monte 1973; Myster and Pickett 1990). For example, *Dactylis glomerata* sowed as the last crop before abandonment is known to dominate and inhibit growth of other species for a few years, but is eventually replaced by clonal perennials (e.g. *Hieracium pratense*; Mysters and Pickett 1990). Species of concern, in terms of succession, are the ones that persist in grasslands but their long-term effect on other grassland species. Research by Vengis (1953) showed that depending on the crop type that was sowed, certain 'weedy' species are associated with different crops and can persist in the seedbank. For example, two 'weedy' species, *Medicago sativa* ssp. *sativa* and

Trifolium pratense, were shown to persist 22 years after initial seeding in an old-field experiment (Crowder et al. 2007).

Dispersal may have more of an effect on the availability of later successional species (Meiners et al. 2007); however, the dispersal of the seeds itself are known to be a limiting factor for the spread of species (Primack and Miao 1992; Tilman 1997; Bischoff 2002). Although the three fields in this study may converge to be similar in 8 to 10 years, given the apparent lack of native seeds in the seedbank, the goal of a native meadow ecosystem would not be met in the initial restoration effort.

Disturbance such as preferential grazing on species can affect succession (Crowder et al. 2007). For example, grazing on *Phleum pratense* by *Thymelicus lineola* (European skipper butterfly) was shown to increase the percent cover of native *Solidago* and *Symphyotrichum spp.* and maintained dominance to prevent dominance by non-native *P. pratense* (Crowder et al. 2007). Disturbance such as tillage may decrease seed predation of common lambsquarter and barnyard grass suggesting that in old-fields, no-till option can be used as a form of biological weed control (Cromar et al. 1999). Both of these species were present in the 2011 plant survey at Boyne Valley Provincial Park. Future research should investigate the no-till option in conjunction with planting for restoration efforts.

Pollen allelopathy of species may inhibit seed germination, seedling emergence, sporophytic growth or sexual reproduction of other species (Murphy 2001) changing plant composition and altering the predicted successional path. Six known pollen-allelopathic species are *Phleum pratense*, *Zea mays* var. *chalquinoconico*, *Hieracium aurantiacum*, *Hieracium pratense*, *Hieracium floribundum*, *Parthenium hysterophorus* (Murphy 2001). Both *Phleum pratense* and *Hieracium aurantiacum* were present in the 2011 plant survey at Boyne Valley Provincial Park. *Phleum pratense* has shown pollen-allelopathic effects on 38 out of 40 grassland species tested (Murphy and Aarssen 1989). *Phleum pratense* also limits seed set in *Danthonia spicata* (Murphy 2000), which was one of the planted experimental species at Boyne Valley Provincial Park, as well as *Elymus repens* (non-native) and *Danthonia compressa* (native; Murphy and Aarssen 1995a). *Hieracium aurantiacum* is known to decrease germination of *Medicago stavia*, *Trifolium repens*, *Vicia cracca* and *Lotus corniculatus*, (Murphy and Aarssen 1995b) which were all found at Boyne Valley Provincial Park. Both these species may reduce other weedy species in Boyne

Valley Provincial Park, but may potentially repress establishment of restoration plantings and alter succession.

Given the changed abiotic and biotic conditions within the leased Ontario Parks land, the meadow ecosystem will be a novel ecosystem (sensu Hobbs et al. 2009). For Boyne Valley Provincial Park, this means a meadow ecosystem that comprises mostly of native meadow plant species with understanding that non-native species will persist. Management should pay special attention to the persistent and/or allelopathic non-native species that may alter the course of succession away from a meadow ecosystem.

Bird Survey

While not the focus of my research, the bird survey was useful in that it indicated that there are several species of concern in the Boyne Valley Provincial Park with some dependent on agriculture/grassland habitat for survival. With the changeover from agriculture leases to park property, there is an increased need for meadow restoration to occur on these soon to be abandoned farmland areas. The decline of the Bobolinks from 2010 to 2011 was likely a change from a hay and wheat field to canola field (Fields 2 and 5). As the fields surrounding the Field 1 study area remained in hay production, the decline in Bobolinks from many to three may be due to the general decline of the species across its range (COSEWIC 2010).

Conclusion

All three fields required planting of native species to introduce a diverse set of new plant species that would not otherwise likely disperse to the area. Without introducing these ‘desired’ species such as the ones in this experiment, it is unlikely that these fields will become a diverse meadow ecosystem. Continued monitoring of these plots should occur for long-term analysis. If persistence of non-native species are dominating the fields eight years after abandonment, consideration of burning coupled with native seed supplementation may be the key (Gross and Emery 2007). Future research should look at planting native species without tilling the land in the hay and annual crop rotation fields and the effect of not tilling on survivorship on planted species.

Chapter 4: Meadow restoration on retired agriculture fields in Boyne Valley Provincial Park: survivorship and growth of restored species

Abstract

Ontario Parks leases approximately 122 ha of land within Boyne Valley Provincial Park to farmers; this agreement expires in December 2015. Restoring these abandoned agriculture fields to meadow ecosystems will meet Ontario Parks' mandate of ecological integrity; however, there is a knowledge gap on how to restore meadow ecosystems in Ontario. As a pilot project, I am looking at survivorship and growth of five native plant species through restoration using plant plugs, seeds, or a combination of plant plugs and seeds. The five species are *Danthonia spicata*, *Elymus trachycaulus* ssp. *trachycaulus*, *Sporobolus cryptandrus*, *Monarda fistulosa* and *Penstemon hirsutus*. Based on survivorship and growth for the first year after planting, my recommendations to Ontario Parks would be to use plant plugs for *Elymus trachycaulus* ssp. *trachycaulus* and plant seeds for *Monarda fistulosa* and *Penstemon hirsutus*. Future research should entail adding more species to the restoration area. Longer-termed research and monitoring will help to better understand and predict ecological succession of restoring meadow ecosystems in Boyne Valley Provincial Park.

Introduction

Boyne Valley Provincial Park contains approximately 122 ha of leased agriculture land, which will expire in December 2015. Converting the land to permanent vegetation cover can be beneficial to both farmers and the environment (Tomalty 2012). Permanent vegetation provides food, nectar and habitat for pollinators (which will help farmers with pollination of their adjacent crops), increases the carbon sequestration, decreases erosion and absorbs wastes (Tomalty 2012). Ontario Parks is currently deciding on a restoration management plan for the forthcoming retired agricultural lands in order to meet their mandate of ecological integrity. The *Provincial Parks and Conservation Reserves Act, 2006* defines ecological integrity as,

> *"…a condition in which biotic and abiotic components of ecosystems and the composition and abundance of native species and biological communities are characteristic of their natural regions and rates of change and ecosystem processes are unimpeded"* (c.12, s.5(2)).

This study will give Ontario Parks a starting plan to restore abandoned fields and it is recognized that generalization of such an approach requires future studies in other locales.

Nonetheless, given that the techniques and physical geography of much of southern Ontario farmland is reasonably similar, the plan arising from my work should be quite useful on its own.

Prior to European contact in the Great Lakes Region (400BP; Storck 2004), the landscape of southern Ontario was historically a mosaic of forests, wetlands, prairies and meadows (see Figure 1 in Delaney et al. 2000). In North America, the literature is confusing in defining how prairies are functionally different from meadows (see Chapter 1). The bottom line, there is no clear definition based on species composition, disturbance regime or soil that distinguishes meadows and prairies. But nevertheless, there is recognition that meadows and prairies are different; however, there needs to be multivariate analysis to quantify the amount of variation between the two communities over space and time.

For the purpose of this dissertation, I am distinguishing a prairie from a meadow ecosystem as follows:

1) I consider prairies as a more stable plant community that is maintained by regular disturbance, ideally fire, from a management perspective.

2) I consider meadows, and indeed this appears to be in line with the prevailing views of North American restoration ecologist, to be transitional communities between grassland and a forest; in other words, there is an absence of disturbance that would maintain a prairie.

Currently, prairies and meadows are some of the most endangered ecological communities in North America (Delaney et al. 2000). As many as 36 species at risk in Ontario (as listed on the provincial *Endangered Species Act, 2007*) require prairie and/or meadow habitats during some component of their life cycle (Appendix A).

Presently, there is a gap in knowledge on how to restore meadow ecosystems in Ontario. As one of the first research projects explicitly focused on meadow restoration in Ontario, this intent was to begin the process of restoring ecological function on abandoned agriculture fields in Boyne Valley Provincial Park. One major challenge in restoration of degraded ecosystems is that unexpected results often occur making it difficult to predict responses (Suding et al. 2004). Unexpected outcomes may arise from restoration activities that focus on restoring historic abiotic features of the system (i.e. successional-based approach) and ignoring the changed abiotic and biotic feedbacks in a degraded system (Suding et al. 2004). Suding et al. (2004) gave several examples where relying on a successional-based approach will lead the restored system to an alternate state. Understanding that restoration at Boyne Valley Provincial Park is on abandoned agriculture land (degraded), the restored land will be treated as a novel ecosystem (sensu Hobbs et al. 2006).

Many of the meadow species are no longer found in agriculture fields across Ontario after repeated tillage and treatment with herbicides (Stephen Murphy personal communication). Boyne Valley Provincial Park is no exception and provides an excellent chance to study meadow restoration. To achieve a meadow ecosystem, we need to first understand which species perform the best as a ground cover during the first year after planting. I chose two herbaceous wildflowers and three grasses that met the following criteria: 1) they are native to Ontario (Gleason & Cronquist 1991) and were not found in the initial plant survey in 2010), 2) they could be grown at a nursery, and 3) They are common species. The species chosen were *Danthonia spicata* (L.), *Elymus trachycaulus* (Link) Gould ex Shinners ssp. *trachycaulus, Sporobolus cryptandrus* (Torr.), *Monarda fistulosa* (L.), and *Penstemon hirsutus* (L.). To identify a cost-effective restoration method for Ontario Parks, I tested the survivorship of the five species using established plant plugs grown at a nursery or sowing the seeds. This study focused on: 1) which treatment(s) and plant species had the best survivorship the first year after planting for plant plugs, seeds or a combination of plant plugs and seeds; and 2) which treatment(s) and plant species had the greatest growth for the first year after planting for plant plugs, seeds or a combination of plant plugs and seeds. The survivorship of plant plugs was expected to be higher than seeds (Wallin et al. 2009) but understanding which species of plant plugs could survive was the first priority (e.g. Burke 2012). This experiment will pilot the development of longer-termed studies to better understand and predict succession for meadow restoration in Boyne Valley Provincial Park.

Methods

Study site, study area, preparation of the soil, and planting of plant plugs and seeds can be found in the methods section of Chapter 3 *Comparing restoration methods on the quality of meadow restoration on former agriculture fields*.

Experimental design

Three transects in a W-shape, to reduce autocorrelation (Forcella et al. 1992), were replicated at all three fields. Each transect was 32 m long with 17 permanent plots per transect. Based on the area and dimensions available in each field, transects were placed to optimize area and were spaced a minimum of 5 m apart to reduce/eliminate seeds blowing to another transect. Each plot was 50 cm x 50 cm for a total area of 2500 cm^2 or 0.25 m^2. Description of the three treatments are as follows:

Transect 1. *Plant Plugs Only* (P): Each plot contains two plant plugs of *Danthonia spicata*, *Elymus trachycaulus* ssp. *trachycaulus*, *Monarda fistulosa*, *Penstemon hirsutus* and *Sporobolus cryptandrus*. Same species plugs were planted approximately 5 cm from one another.

Transect 2. *Plant Seeds Only* (S): Each plot contains 0.6 mL x 2 of *Danthonia spicata* seeds, 0.6mL x 2 of *Elymus trachycaulus* ssp. *trachycaulus* seeds, 0.3mL x 2 of *Monarda fistulosa* seeds, 0.3mL x 2 of *Penstemon hirsutus* seeds and 0.6mL x 2 of *Sporobolus cryptandrus* seeds.

Transect 3. *Plant Plugs and Seeds* (PS): Each plot contains 1 plant plug of the 5 species listed above and 0.6 mL of *Danthonia spicata* seeds, 0.6mL of *Elymus trachycaulus* ssp. *trachycaulus* seeds, 0.3mL of *Monarda fistulosa* seeds, 0.3mL of *Penstemon hirsutus* seeds and 0.6mL of *Sporobolus cryptandrus* seeds.

Study Species

A plant survey was conducted in April and May 2010 prior to tillage of the land and throughout the summer on the 1-year Fallow (no-till) treatment transects. From the plant surveys, five plant species were chosen based on the criteria that they are native meadow species originally found within Dufferin County, the plant species were not identified in the 2010 plant survey, and the species were able to be grown at St Williams Nursery & Ecology Centre: Pterophylla Native Plants and Seeds, Long Point Ontario. The five plant species chosen were *Elymus trachycaulus* ssp. *trachycaulus* (slender wheatgrass), *Sporobolus cryptandrus* (sand dropseed), *Danthonia spicata* (poverty oatgrass), *Monarda fistulosa* (wild bergamot) and *Penstemon hirsutus* (hairy beardtongue).

Danthonia spicata* (poverty oat grass*)

Danthonia spicata is a densely tufted, shallow rooted perennial grass with fibrous roots (Dore and McNeill 1980; Darbyshire and Cayouette 1989; Figure 4-1).

Figure 4-1: Pencil drawing of *Danthonia spicata.* (USDA, NRCS 2013)

It can spread vegetatively at a rate of 1-2cm per year through tillers from the basal nodes (Dore and McNeill 1980); however, no true stolons or rhizomes are present (Dore and McNeill 1980). It is native throughout North America and prefers dry woods in sandy or stony soil (Gleason & Cronquist 1991). The culms can range from 10-100cm high either erect or slightly bent at the lower nodes (Darbyshire and Cayouette 1989).

It has two types of inflorescences, terminal (chasmogamous) and basal (cleistogenes) (Darbyshire and Cayouette 1989). Having dimorphic seeds makes it a better competitor to exploit different types of environments (Clay 1983). It flowers (terminal inflorescens) May-June with seeds maturing late June-July (Darbyshire and Cayouette 1989). *Danthonia spicata* is drought tolerant and can live in nutrient-poor soils (Darbyshire and Cayouette 1989). The seeds of *D. spicata* are long-lived (over 60 years) within soils (Livingston & Allessio 1968; Abrams & Dickman 1984). Ecologically, it is important for spring forage for deer (*Odocoileus virginianus*; Kalmbacher and Waskko 1997) and protecting soils from erosion and nutrient depletion (Chichester 1977).

Elymus trachycaulus* ssp. *trachycaulus (*slender wheatgrass*)

Elymus trachycaulus ssp. *trachycaulus* is a tufted erect perennial grass with short rhizomes (Looman 1982; Howard 1992; Figure 4-2).

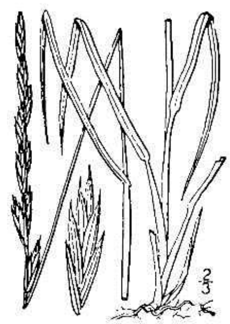

Figure 4-2: Pencil drawing of *Elymus trachycaulus* ssp. *trachycaulus.* (USDA, NRCS 2013)

The root system is dense with coarse and fine fibrous roots that can extend 30 cm in depth (Howard 1992). It is native in Canada and parts of United States and is found in various habitats (Gleason & Conquist 1991). Prior to 1940, it was grown for hay (Looman 1982). It is self-fertile or wind-pollinated with heavy seed production (Hafenrichter et al. 1949; Hardy 1989; Howard 1992) flowering in July-August and seeds ripening in August-September (Howard 1992). Seeds can remain dormant in the seedbank for 3 to 6 years (Howard 1992). Reproduction is mainly through seed dispersal and seedling establishment; however, both seed production and vegetative reproduction, through tillering, has been noted (Hardy 1989; Howard 1992). *Elymus trachycaulus* can grow in dry to moist, medium-textured soil and does best on sandy loam soils (Howard 1992). It has a high salt tolerance (Looman 1982; Howard 1992) with pH levels from moderately acid to alkaline but has been found in soils with a pH as high as 8.9 (Hardy 1989; Howard 1992).

Sporobolus cryptandrus (**sand dropseed)**

Sporobolus cryptandrus is a perennial grass found in dry and sandy soils, and is native in parts of North America (Gleason & Cronquist 1991; Figure 4-3).

Figure 4-3: Pencil drawing of *Sporobolus cryptandrus.* (USDA, NRCS 2013)

It reproduces through grains produced cleistogamously and lacks rhizomes (Dore and McNeill 1980). Seeds can germinate 20 years after being in the seedbank (Goss 1924).The plant can range between 30-100 cm height (Quinn and Ward 1969). It is commonly found on sandy soils but can survive on a wide range of soil conditions (Quinn and Ward 1969). It has been found in a range of soil pH levels from 6.5 to 9.0 (Quinn and Ward 1969).

Monarda fistulosa (**wild bergamot*****)***

Monarda fistulosa is an aromatic herbaceous perennial found in upland woods, thickets and prairies and is native in most of North America (Gleason & Conquist 1991; Figure 4-4).

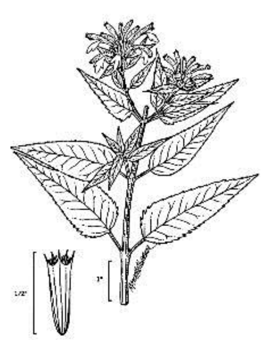

Figure 4-4: Pencil drawing of *Monarda fistulosa.* (USDA, NRCS 2013)

It has purple flowers between June to September (Gleason & Conquist 1991). *Monarda fistulosa* is pollinated by bees and butterflies (Cruden et al. 1984). It can grow in a wide range of soils, dry and moist soils, acid to lime, sand to clay, but is less tolerant of flooding (Lady Bird Johnson Wildflower Center 2013). It grows best in soil pH levels between 6.8-7.2 (Lady Bird Johnson Wildflower Center 2013). Ecologically important for birds and butterflies (Lady Bird Johnson Wildflower Center 2013).

***Penstemon hirsutus* (northeastern beardtongue)**

Penstemon hirsutus flowers between May to July, is found in dry woods and fields and is native to parts of North America (Gleason & Conquist 1991; Figure 4-5).

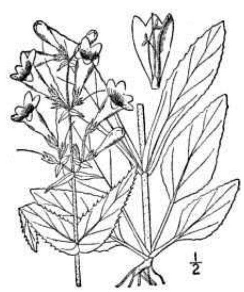

Figure 4-5: Pencil drawing of *Penstemon hirsutus.* (USDA, NRCS 2013)

It is a perennial flower with erect hairy stems with many from the same rhizome (Lady Bird Johnson Wildflower Center 2013). Seeds are 0.7-1 mm^2 and the fruit is 8-9 mm^3 (Clements et al. 1998). The plants are known to reach 40c m-61 cm in height (Lady Bird Johnson Wildflower Center 2013). It prefers dry, well-drained soils (Lady Bird Johnson Wildflower Center 2013). It is a larval host and nectar source for *Euphydrayas phaeton* (Baltimore butterfly; Lady Bird Johnson Wildflower Center 2013). The primary pollinators are bumblebees; in Tennessee and Kentucky the two primary species were *Bombus pennsylvanicus* and *Bombus bimaculatus* (Clements et al. 1999).

Survivorship Surveys

Survivorship data was collected bi-weekly (between eight and eighteen days apart) for six rounds during summer 2011 between June 16t^{h} and August 28th 2011. Data collected in each round included total number of plants, three leaf areas (leaf lengths and widths), plant height (leaf), spread (largest two measurements perpendicular to each other), total number of flower stalks, height of three flower stalks (to be averaged later) and the total number of flowers/seeds on each of the three stalks that were measured for flower stalk height (for *Monarda fistulosa* and *Penstemon hirsutus*). A second year of survivorship was collected in 2012. Surveys were done June 2nd, July 14th and August 10th 2012.

Variables Measured

I measured 7 phenological response variables related to survivorship and growth. To indicate survivorship I looked at the number of present seedlings to determine the species ability to establish. For competition, I looked at the species ability to reproduce through number of flower stalks, number of seeds and flowers, and height of tallest flower. For growth in terms of competition, I looked at leaf size, height, and the area the species occupied.

- Total number of plants: the total number of plants alive for each of the five species in the plot during the six visits in 2011. In 2012, plant species were indicated if they were present (alive) or absent (none alive) in the plot during the three visits in 2012.

- Leaf area: the three largest leaves were chosen during each visit and the lengths (longest part) and widths (widest part) were measured. Widths were difficult to measure with a digital caliper because leaves were curling and a ruler was used instead for all length and width measurements. When using a ruler, measurements were always rounded up (for example, if approximately 1.5mm, it was recorded as 2mm). For *Elymus trachycaulus* ssp. *trachycaulus*, leaf length was measure on leaves from the flower stalks if present. If no leaves were present on flower stalk, then basal leaves were measured for length and width.

- Plant height: The tallest green leaf (even if it is bent) was measured from ground to tallest green point in the plot without manipulating the plant. If a flower was taller than the tallest leaf, both flower and leaf were measured and recorded. The leaf was always used for plant height.

- Spread: the spread was calculated measuring two longest lengths perpendicular to one another. Both leaves and roots were considered for spread.

- Total number of flower stalks: the total number of flower stalks alive in the plot during the visit were counted.

- Height of flower stalks: the three tallest flowers were measured from the base of the flower stalk to the tip of the flower.

- The total number of seeds and flowers on the measured flower stalks (that were measured for height) for *Monarda fistulosa* and *Penstemon hirstus* were counted.

Soil Type

The three experimental locations within Boyne Valley Provincial Park contained different soil series, type, group, parent material and drainage (Table 4-1).

Table 4-1: Soil type at each location based on Soil Survey of Dufferin County Ontario, Report No 38 of the Ontario Soil Survey (1963)

Location	Soil Series	Type	Great Group	Parent Material	Drainage
Over 30-year Old Field (Field 1)	Crombie	Silt loam	Dark Grey Gleysolic	Loess or alluvium over loam till	Poor
7-years Hay (Field 2)	Hillsburgh	Sandy loam	Grey brown Podzolic	Outwash fine sand	Good
Annual Crop Rotation (Field 5)	Caledon	Fine sandy loam	Grey brown Podzolic	Fine sandy loam material over outwash gravel	Good

Soil sampling

One cup of soil sample (minimum) per plot was collected between September 27th and October 10th 2010. Soil samples were collected in plastic sampling bags and stored in a safe, dry location until they were analysed for levels of nitrogen, phosphorus and potassium. Analyses for nitrate-nitrogen, potassium and phosphorus were conducted in the Ecology Lab at the University of Waterloo April 2011. Soil nutrient measurements were taken with the *LaMotte Smart 2 Colorimeter*. Soil moisture and pH levels were tested in the field using a Kelway Soil® acidity and moisture tested Model HB-2 on August 17th 2011.

Statistical Analyses

Survivorship and growth data was analysed using repeated measures analysis of variance test and an ANOVA. Fisher's exact test was used to compare the percentage of survivorship between the 1^{st} and 2^{nd} year after planting. Mann-Whitney U tests were used to compare nutrient levels, moisture levels and pH levels between treatments. MANOVAR were conducted using R analysis program, Mann-Whitney U and all graphs were conducted using Statistica© Version 9.0 (StatSoft 2009). Data were considered significantly different at $p < 0.05$.

Results

The results for the survivorship and growth experiment for the first year after planting indicate that plant plugs for *Elymus trachycaulus* ssp. *trachycaulus*, and both plant plugs and seeds for *Monarda fistulosa*, and *Penstemon hirsutus* had the highest survivorship and growth (Table 4-2 to 4-6). Flowers were only produced from planted plugs and not from seeds for the first year after planting.

Danthonia spicata

Table 4-2: MANOVAR testing survivorship and growth characteristics of *Danthonia spicata* to 9 different treatments. Sampling was conducted in 2011 in Boyne Valley Provincial Park, Ontario, Canada. p = 0.05 and *** is p < 0.001.

Variable	Treatment		Time			Time * Treatment		
	F	***p***	***Pillai***	***F***	***p***	***Pillai***	***F***	***p***
Total # species	11.45	***	0.11	15.37	***	0.15	19.96	***
Leaf Area	13.49	***	0.18	22.67	***	0.24	31.73	***
Plant Height	12.23	***	0.64	70.23	***	0.67	72.09	***
Spread (foliage)	11.62	***	0.26	33.58	***	0.34	39.90	***
Flower Height	14.91	***	0.77	83.41	***	0.85	90.15	***
Flower Number	-	-	-	-	-	-	-	-
Stalk Number	-	-	-	-	-	-	-	-

Tests were based on data collected from 153 plots observed between mid-June through to end of August 2011. For treatment (between subjects effect) data are reported using standard ANOVA F and p. For time and time x treatment (within-subjects effects), data are reported using F, p, and Pillai's Trace because Pillai's test for significant difference of the repeated factor of time (and time x density) within subjects.

The significant Time X Treatment interactions indicated that the effects on survivorship and growth of the treatment changed over the growing season (time). Flowering plants was minimal and did not produce ecological relevance for *Danthonia spicata.* Overall, Plugs Only at the Over 30-year Old Field and all three treatments (Plugs Only, Seeds Only, Plugs and Seeds) at the Annual Crop Rotation field had the highest success for survivorship (Figure 4-6). The leaf area and the plant height were greatest at the Plugs Only treatment at Over 30-year Old Field and Annual Crop Rotation field as well as the Plugs and Seeds at Annual Crop Rotation field. Spread was largest and the flower height was tallest at the Plugs Only treatment at the Over 30-year Old Field.

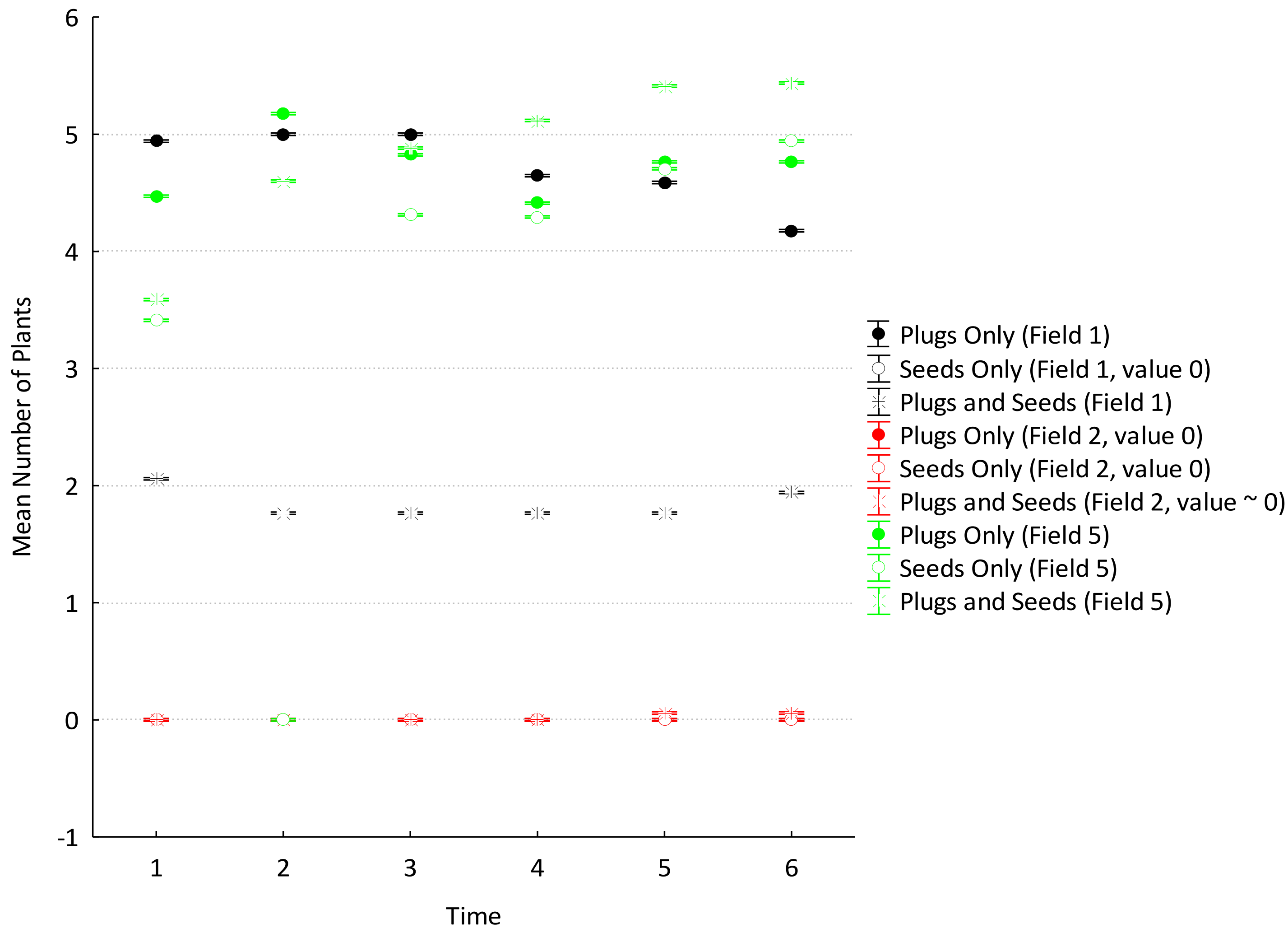

Figure 4-6: Mean number (N=17) of *Danthonia spicata* plants counted in 9 treatments over 6 visits intervals in 2011. Standard error bars were not used for visual ease and error bars were set at a constant 0.01. Missing data was deleted and mean was calculated from remaining data. Missing data included: Field 5 Seeds Only, 9 data points from time 2, 1 data point from time 3; Field 5 Plugs and Seeds, 2 data points from time 2.

Elymus trachycaulus* ssp. *trachycaulus

Overall, the Plugs and Seeds treatment and the Plugs Only treatment at Over 30-year Old Field and Annual Crop Rotation had the highest survivorship (Table 4-3; Figure 4-7).

Table 4-3: MANOVAR testing survivorship and growth characteristics of *Elymus trachycaulus* ssp. *trachycaulus* to 9 different treatments. Sampling was conducted in 2011 in Boyne Valley Provincial Park, Ontario, Canada. P = 0.05 and *** is p < 0.001.

Variable	Treatment			Time			Time * Treatment	
	F	*p*	Pillai	F	*p*	Pillai	F	*p*
total # species	10.13	***	0.10	13.16	***	0.17	23.14	***
Area	17.89	***	0.25	30.93	***	0.47	56.07	***
Height	10.02	***	0.69	76.44	***	0.73	79.42	***
Spread	10.17	***	0.72	77.31	***	0.81	87.68	***
Flower Height	17.55	***	0.79	86.02	***	0.84	89.93	***
Flower Number	-	-	-	-	-	-	-	-
Stalk Number	16.78	***	0.27	34.16	***	0.56	61.86	***

The Plugs and Seeds and Plugs Only treatment at Over 30-year Old Field had the largest leaf area and flower heights. The largest spread and flower stalks were at the Plugs Only treatment at the Over 30-year Old Field. Plant height was tallest at Plugs and Seeds and Plugs Only treatments at Over 30-year Old Field and Annual Crop Rotation as well as the Plugs Only treatment at 7-years Hay field.

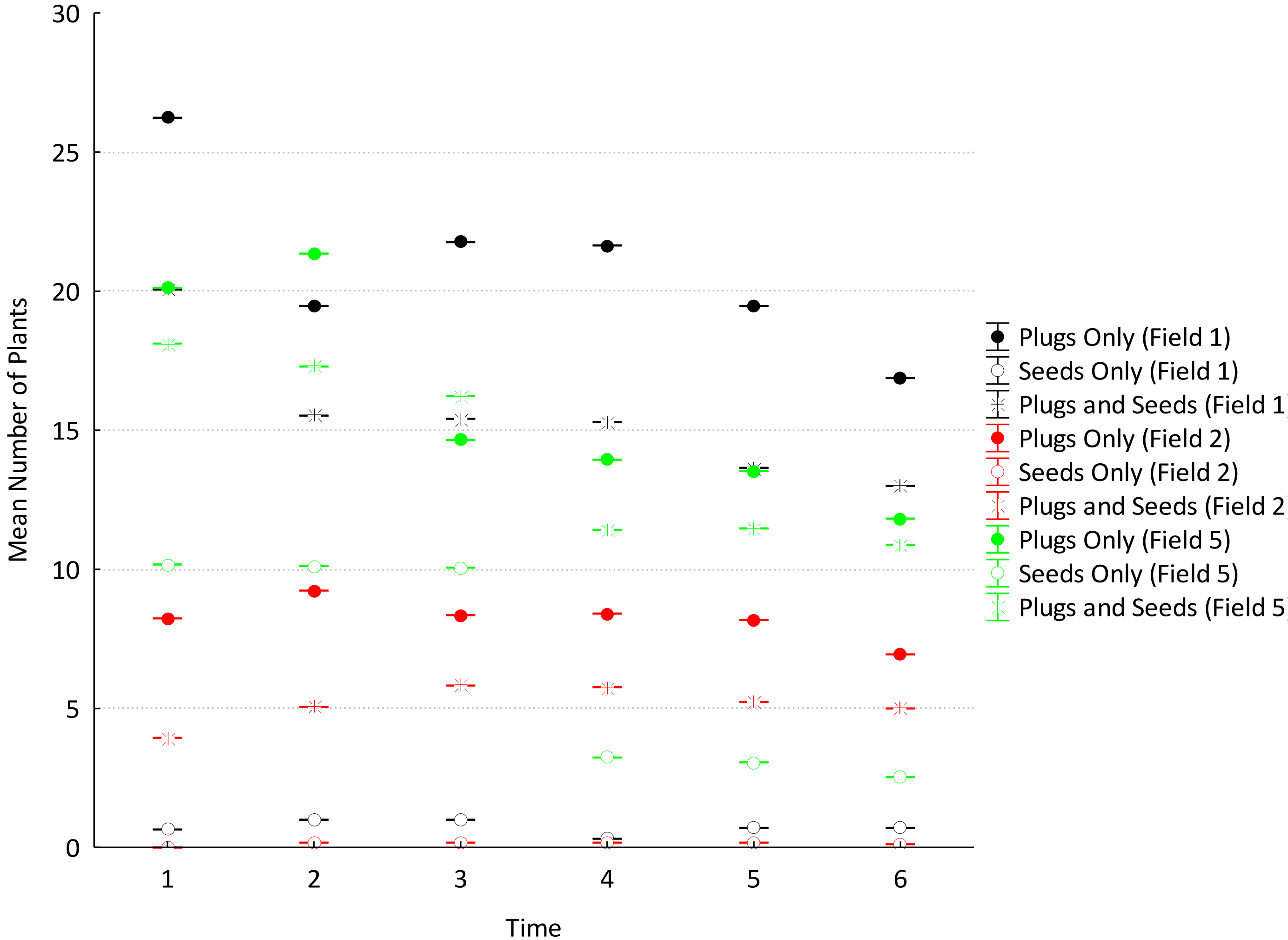

Figure 4-7: Mean number (N=17) of *Elymus trachycaulus* ssp. trachycaulus plants counted in 9 treatments over 6 visits intervals in 2011. Standard error bars were not used for visual ease and error bars were set at a constant 0.01. Missing data was deleted and mean was calculated from remaining data. Missing data included: Field 1, Seeds Only, 1 data point from time 4.

Sporobolus cryptandrus

No seedlings grew from Seed Only or at the Plugs and Seeds treatment at 7-years Hay field. There was no significant difference in survivorship of *S. cryptandrus* if the plant grew (Table 4-4; Figure 4-8).

Table 4-4: MANOVAR testing survivorship and growth characteristics of *Sporobolus cryptandrus* to 9 different treatments

Variable	**Treatment**			**Time**			**Time * Treatment**	
	F	***p***	**Pillai**	**F**	***p***	**Pillai**	**F**	***p***
total # species	11.22	***	0.12	15.87	***	0.15	19.92	***
Area	13.19	***	0.14	18.53	***	0.22	26.15	***
Height	23.27	***	0.58	63.16	***	0.28	33.47	***
Spread	21.08	***	0.41	45.70	***	0.30	35.36	***
Flower Height	-	-	-	-	-	-	-	-
Flower Number	-	-	-	-	-	-	-	-
Stalk Number	-	-	-	-	-	-	-	-

The leaf area, plant height and spread were all highest at the Plugs and Seeds treatment at the Over 30-year Old Field. No flowers grew the first year after planting for *S. cryptandrus*.

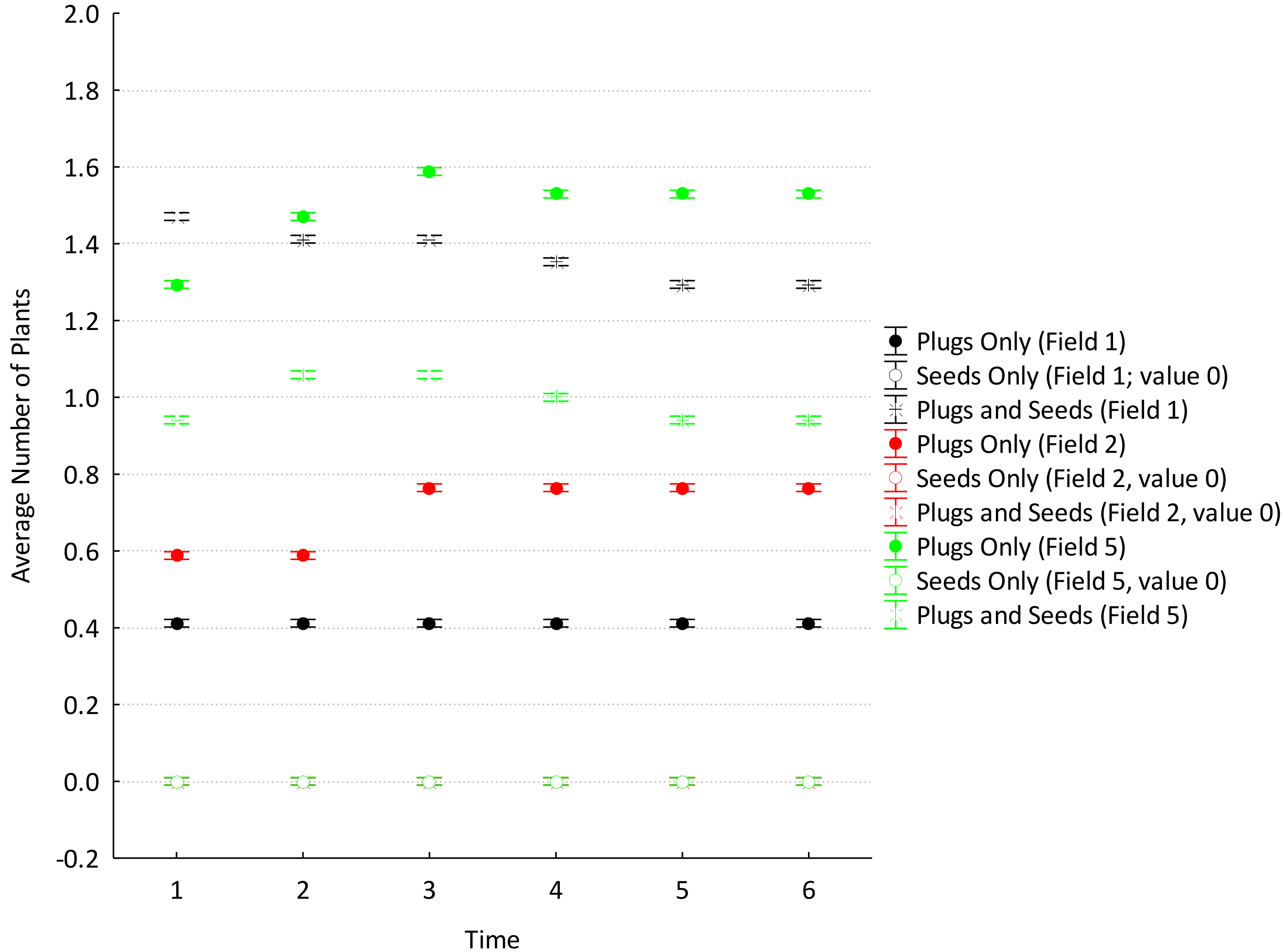

Figure 4-8: Mean number (N=17) of *Sporobolus cryptandrus* plants counted in 9 treatments over 6 visits intervals in 2011. Standard error bars were not used for visual ease and error bars were set at a constant 0.01.

Monarda fistulosa

The highest survivorship was at all the treatments at Annual Crop Rotation field and the Plugs Only treatment at the Over 30-year Old Field (Table 4-5; Figure 4-9).

Table 4-5: MANOVAR testing survivorship and growth characteristics of *Monarda fistulosa* to 9 different treatments

Variable	**Treatment**			**Time**			**Time * Treatment**	
	F	***p***	**Pillai**	**F**	***p***	**Pillai**	**F**	***p***
total # species	15.70	***	0.14	10.12	***	0.24	31.47	***
Area	20.42	***	0.25	37.89	***	0.68	75.39	***
Height	22.79	***	0.69	63.11	***	0.76	83.08	***
Spread	19.35	***	0.72	60.09	***	0.88	93.27	***
Flower Height	6.18	*	0.09	13.86	**	0.03	1.75	0.157
Flower Number	4.23	*	0.07	10.69	*	0.01	1.16	0.272
Stalk Number	4.16	*	0.08	11.91	*	0.02	1.47	0.203

Leaf area, plant height and flower height were largest and highest at the Plugs and Seeds treatment at the Over 30-year Old Field. The spread, number of flowers and number of stalks were greatest at both the Plugs and Seeds and Plugs Only treatment at the Over 30-year Old Field.

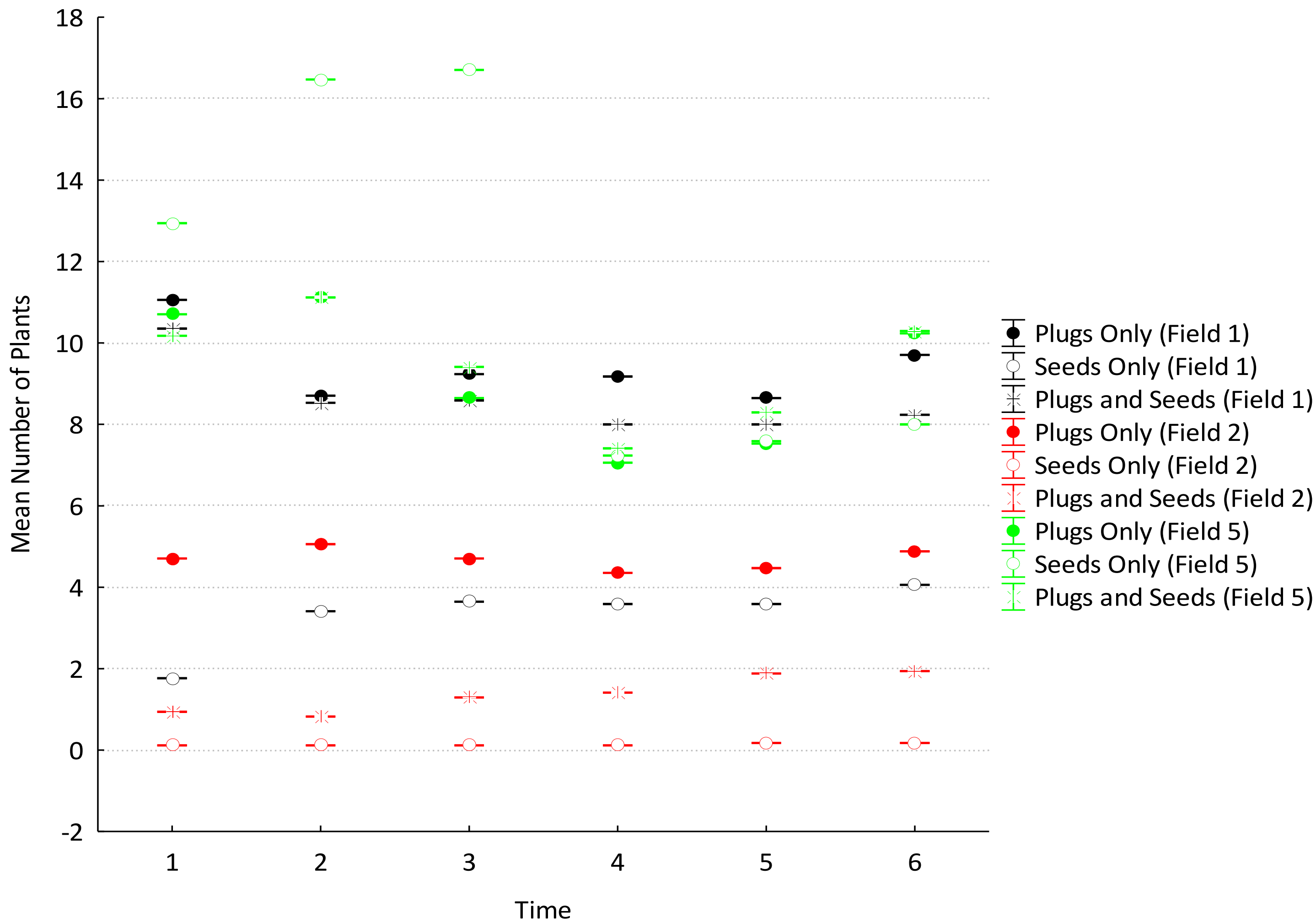

Figure 4-9: Mean number (N=17) of *Monarda fistulosa* plants counted in 9 treatments over 6 visits intervals in 2011. Standard error bars were not used for visual ease and error bars were set at a constant 0.01.

Penstemon hirsutus

The highest survivorship for *P. hirsutus* was at the Seeds Only treatment at the Over 30-year Old Field (Table 4-6; Figure 4-10).

Table 4-6: MANOVAR testing survivorship and growth characteristics of *Penstemon hirsutus* to 9 different treatments

Variable	Treatment		Time			Time * Treatment		
	F	*p*	Pillai	F	*p*	Pillai	F	*p*
total # species	14.17	***	0.14	19.43	***	0.21	25.60	***
Area	17.26	***	0.18	23.57	***	0.29	33.41	***
Height	19.04	***	0.77	84.97	***	0.74	79.53	***
Spread	10.65	***	0.64	69.55	***	0.79	83.99	***
Flower Height	8.27	**	0.39	44.71	***	0.11	15.80	***
Flower Number	9.45	**	0.16	20.52	***	0.10	14.05	***
Stalk Number	3.33	*	0.12	15.86	***	0.05	3.37	*

The largest leaves were at the Plugs Only treatment at the Over 30-year Old Field. Plant height was tallest at the Plugs and Seeds and Plugs Only treatments at the Over 30-year Old Field as well as the Plugs Only treatments at the Annual Crop Rotation field. Spread was greatest at Plugs and Seeds and Plugs Only treatment at Over 30-year Old Field. Flower height was tallest at Plugs and Seeds treatment in the Over 30-year Old Field and Plugs Only treatment at 7-years Hay and Annual Crop Rotation. The number of flowers had the highest count at the Plugs and Seeds and Plugs Only treatment at 7-years Hay field. The number of flower stalks did not differ among the sites if flower stalks were present.

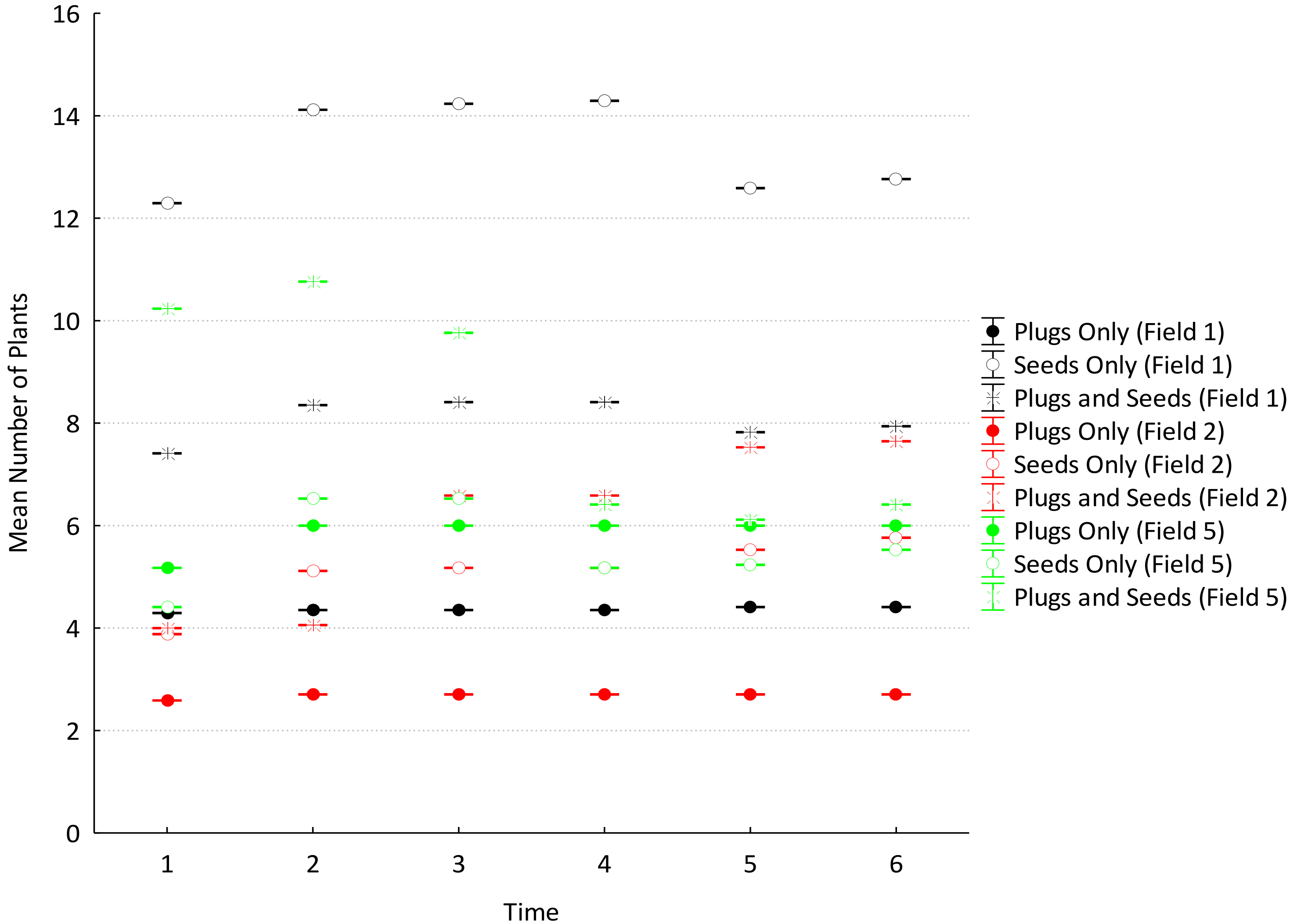

Figure 4-10: Mean number (N=17) of *Penstemon hirsutus* plants counted in 9 treatments over 6 visits intervals in 2011. Standard error bars were not used for visual ease and error bars were set at a constant 0.01.

Survivorship for the Second Year After Planting

The percentage of *D. spicata* that grew in the second year after planting (29%) was significantly greater than the percentage that grew the first year after planting (0%) in Seeds Only treatment in the Over 30 year Old Field, Fisher's exact test, $p = 0.045$ (Figure 4-11).

Elymus trachycaulus ssp. *trachycaulus* at treatments Plugs and Seeds at 7-year Hay field, and Plugs and Seeds and Seeds Only at the Annual Crop Rotation field, the percentage that grew in the second year (35%, 47% and 41% respectively) after planting was significantly less than the percentage that grew the first year after planting (94.1%, 100% and 94.1% respectively), Fisher's exact test, $p < 0.001$, $p < 0.001$ and $p = 0.002$ respectively (Figure 4-12).

Sporobolous cryptandrus at treatments Plugs and Seeds at the Over 30-year Old Field and Annual Crop Rotation field, and the Plugs Only at 7-years Hay field, the percentage that grew in the second year (29%, 24%, 6% respectively) after planting was significantly less than the percentage that grew the first year (84%, 65%, and 47% respectively) after planting, Fisher's exact test, $p = 0.005$, $p = 0.04$ and $p = 0.02$ respectively (Figure 4-13).

There were no significant differences between 2011 and 2012 survivorship for *M. fistulosa* or *P. hirsutus* (Figure 4-14 to 4-15).

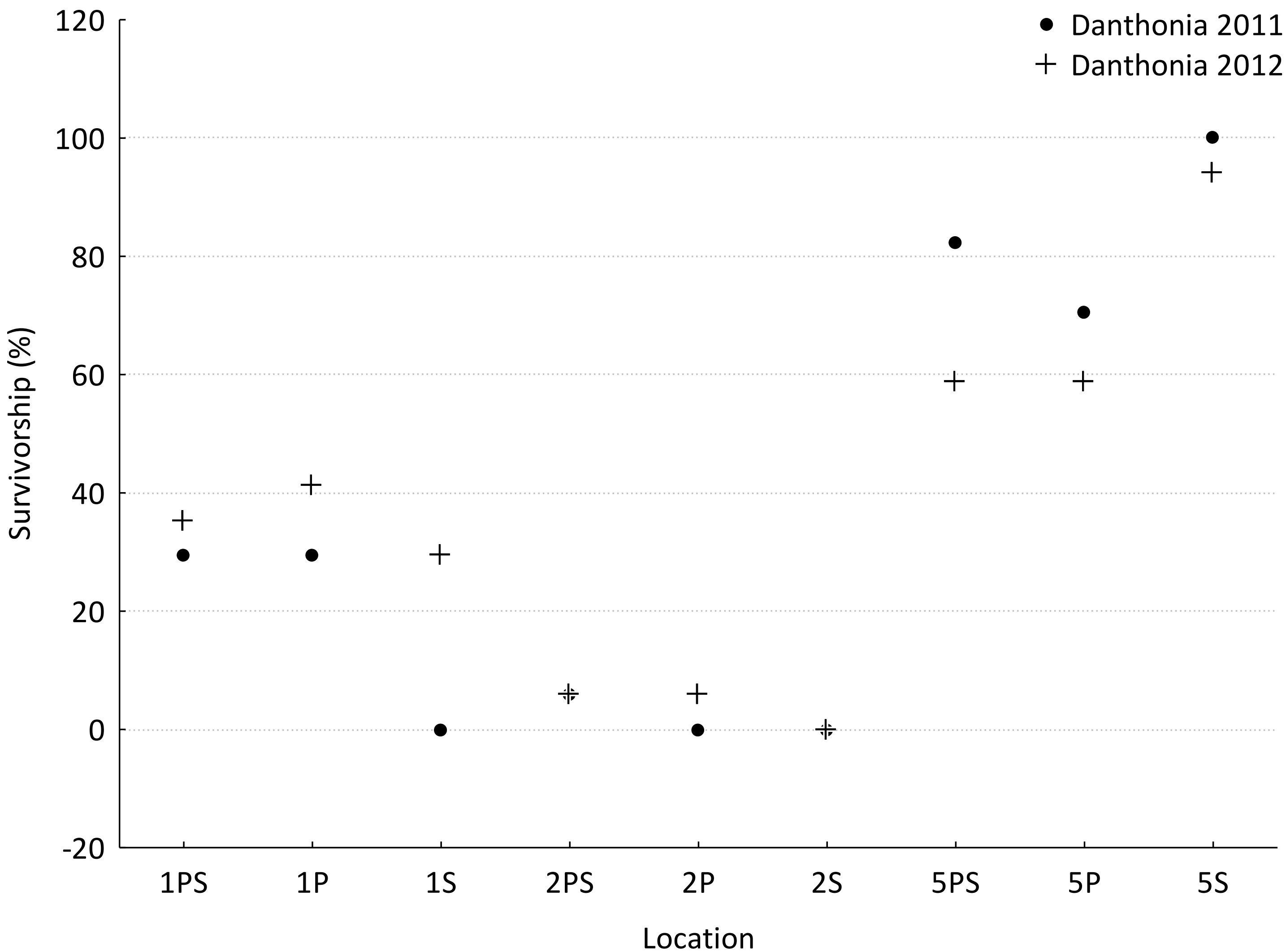

Figure 4-11: Percentage of *Danthonia spicata*, present within in each of the 9 treatment in year 2011 and 2012. Percentage was calculated by present (1) or absent (0) within a plot for a maximum of 17 counts per treatment for each year.

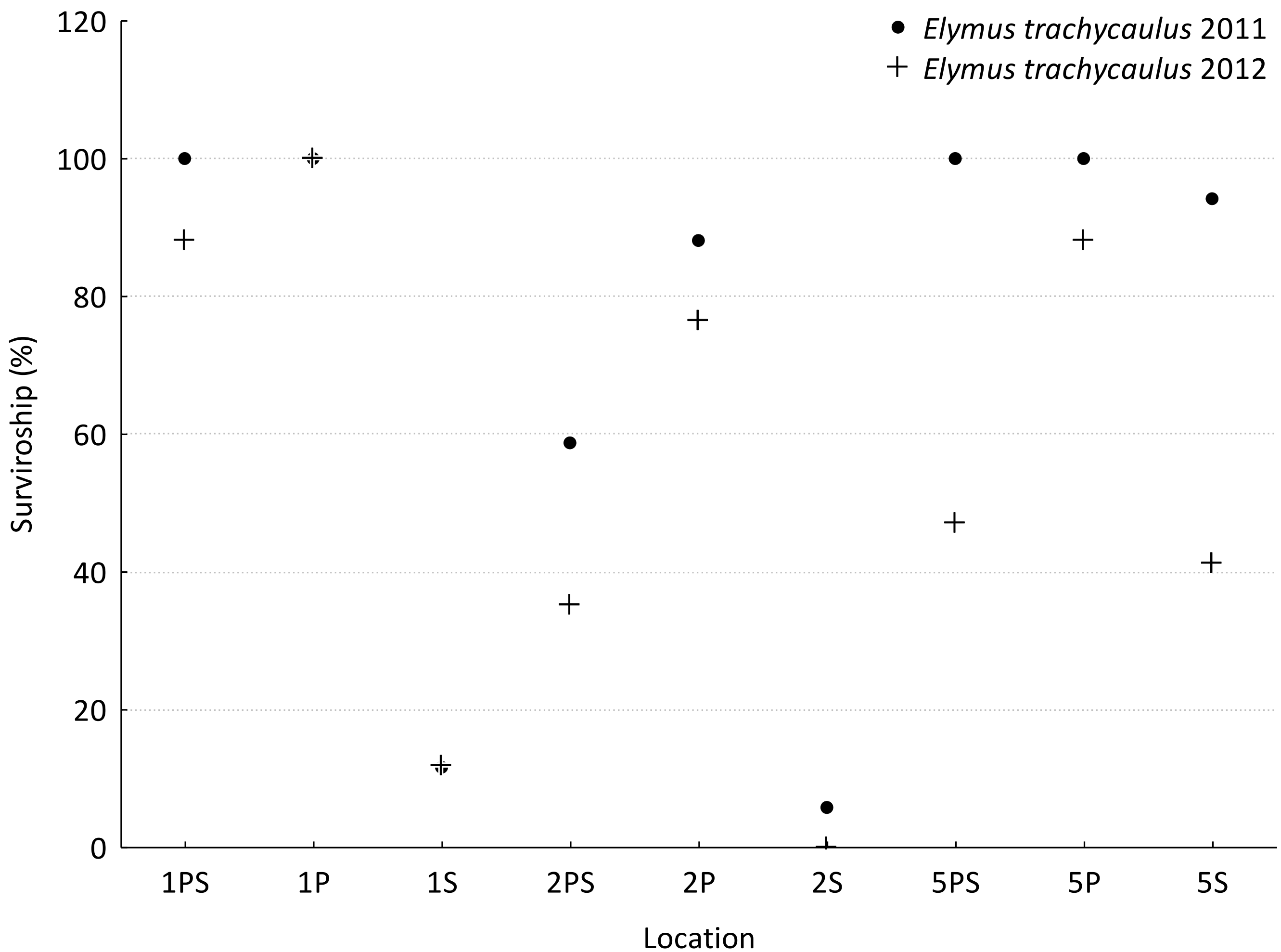

Figure 4-12: Percentage of *Elymus trachycaulus* ssp. *trachycaulus* present within in each of the 9 treatment in year 2011 and 2012. Percentage was calculated by present (1) or absent (0) within a plot for a maximum of 17 counts per treatment for each year.

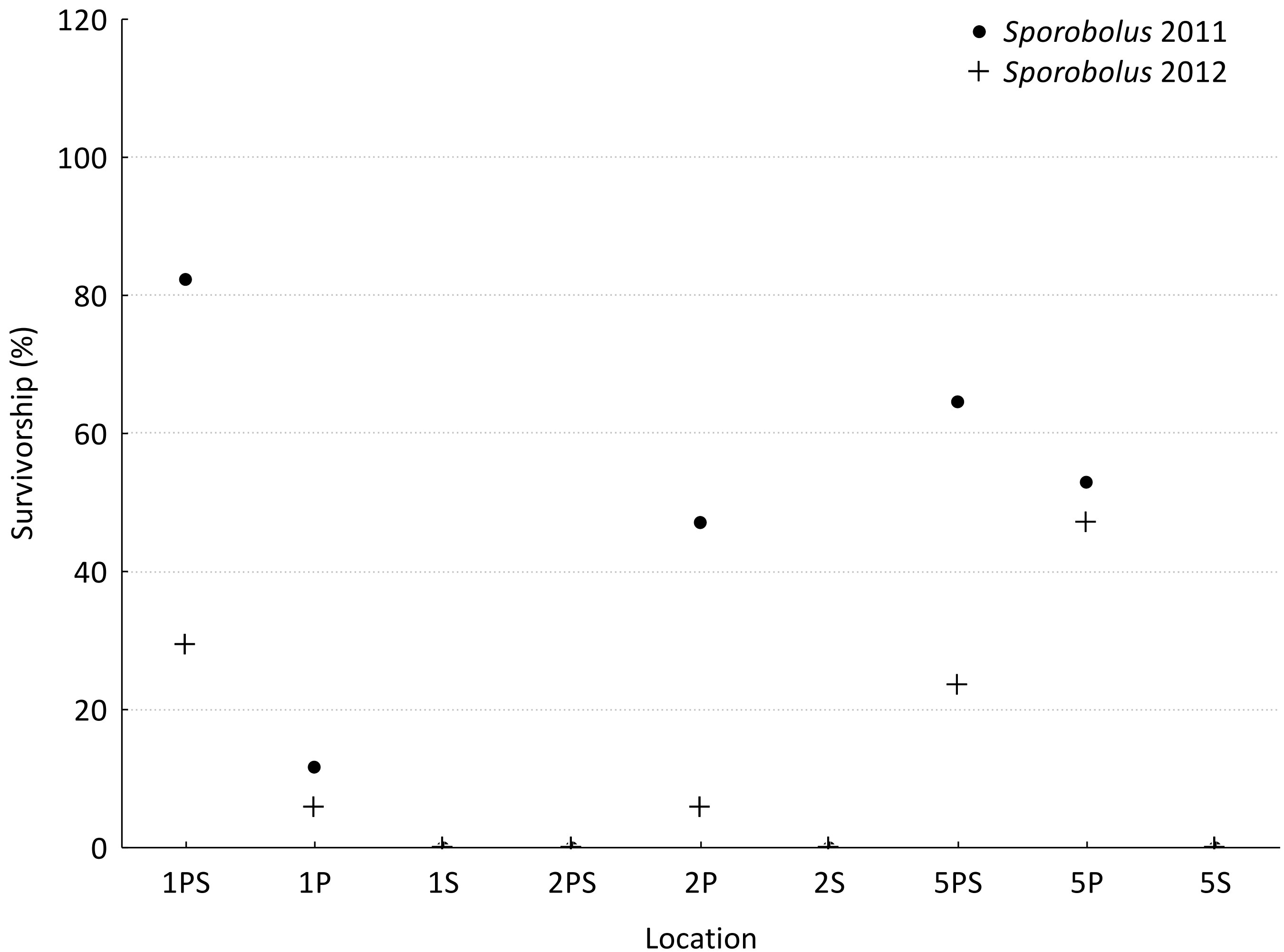

Figure 4-13: Percentage of *Sporobolus cryptandrus* present within in each of the 9 treatment in year 2011 and 2012. Percentage was calculated by present (1) or absent (0) within a plot for a maximum of 17 counts per treatment for each year.

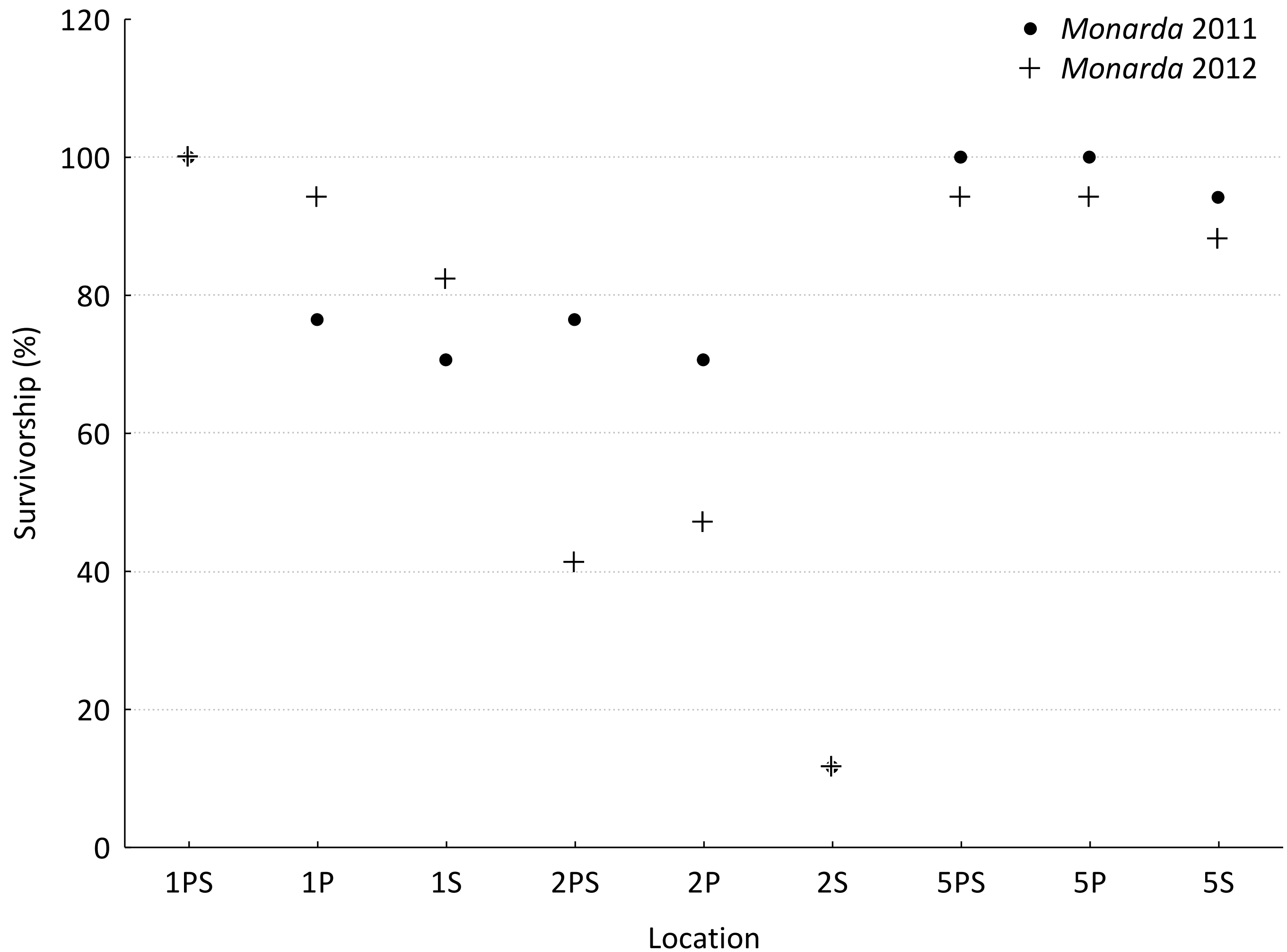

Figure 4-14: Percentage of *Monarda fistulosa* present within in each of the 9 treatment in year 2011 and 2012. Percentage was calculated by present (1) or absent (0) within a plot for a maximum of 17 counts per treatment for each year.

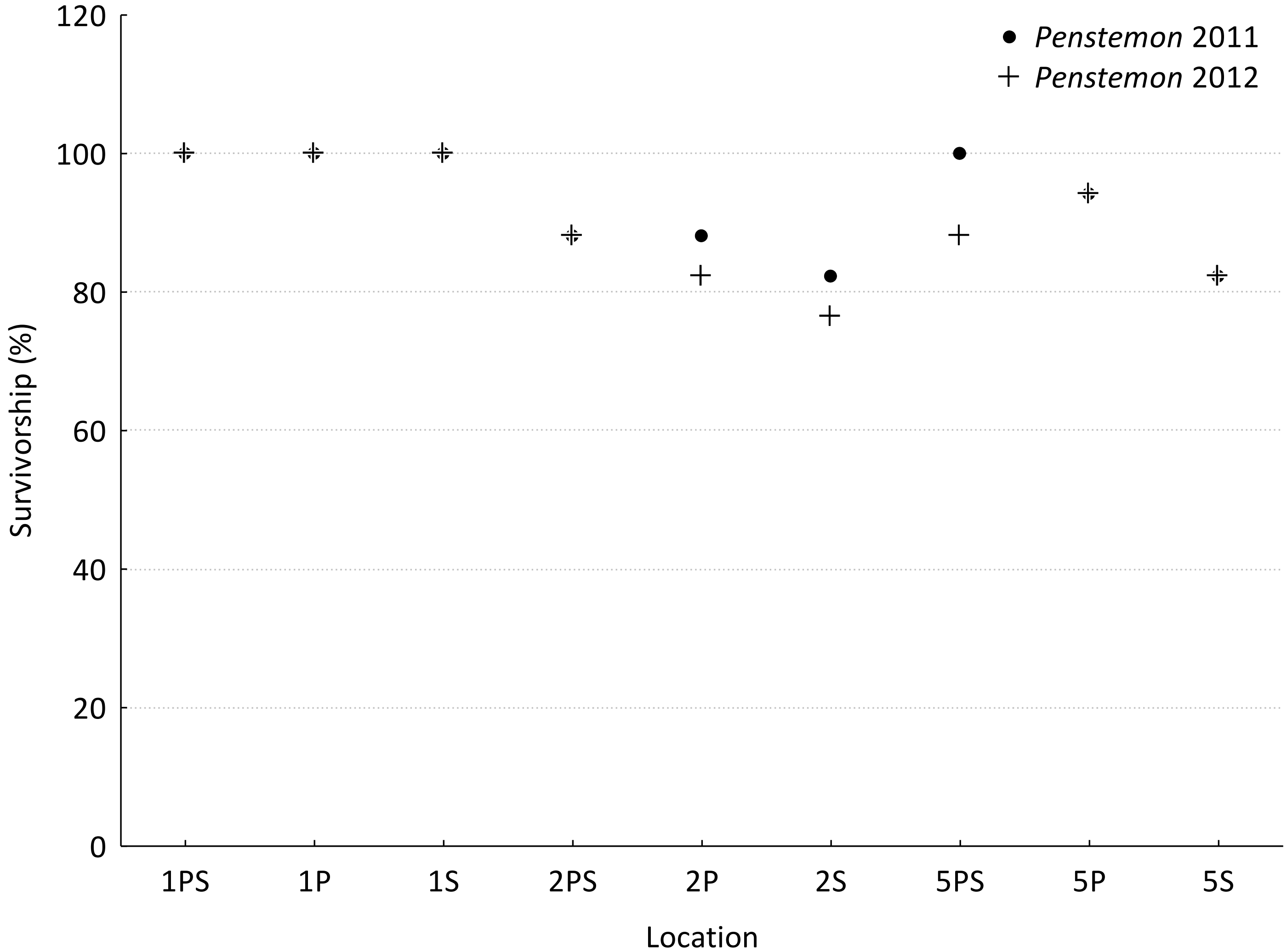

Figure 4-15: Percentage of *Penstemon hirsutus* present within in each of the 9 treatment in year 2011 and 2012. Percentage was calculated by present (1) or absent (0) within a plot for a maximum of 17 counts per treatment for each year.

Soil - Moisture Levels

Mann-Whitney U tests indicated that the 7-years Hay field (Field 2) had the highest moisture (60-90%), then the Over 30-year Old Field (Field 1; 45-60%) and the most dry was the Annual Crop Rotation field (Field 5; 30-60%; Figure 4-16).

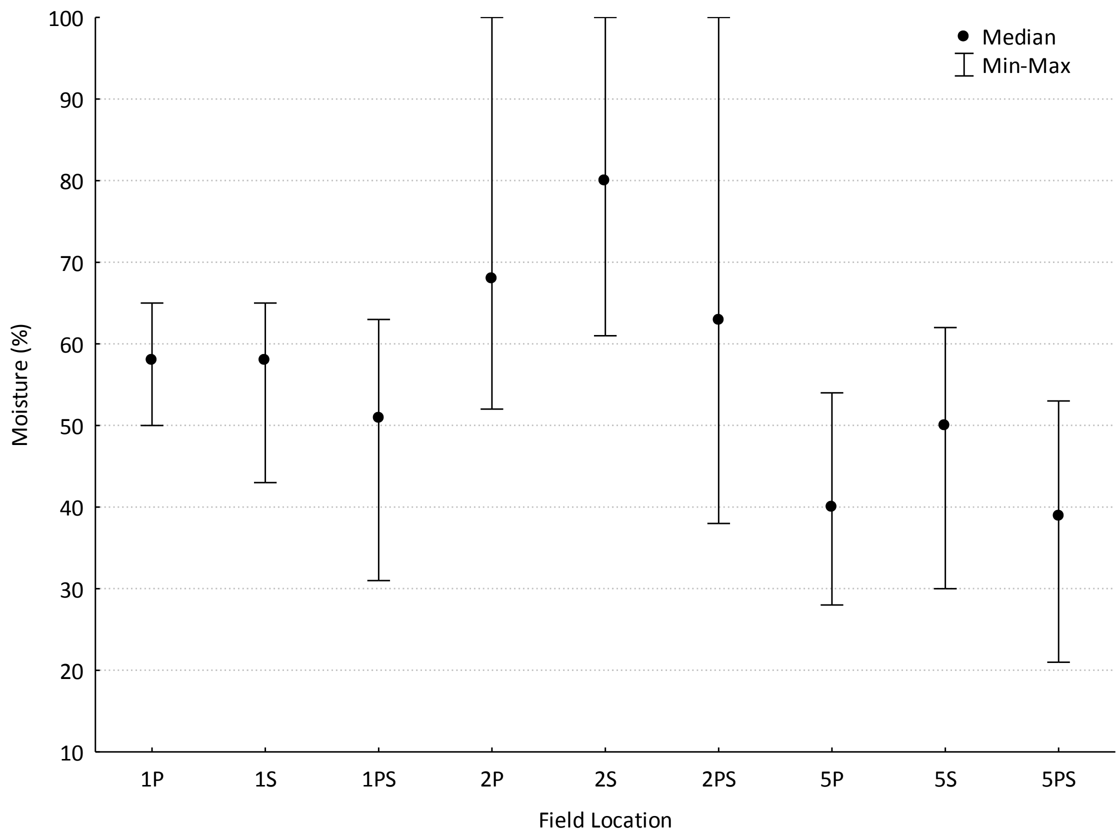

Figure 4-16: Percent moisture with median and min-max values for the 9 treatments. Treatments are listed with P = Plant Plugs Only, S = Plant Seeds Only, PS = Plant Plugs and Seeds. The numbers indicate Field 1 (Over 30-year Old Field), Field 2 (7-years Hay field) and Field 5 (Annual Crop Rotation).

The Seeds Only treatment at 7-years Hay field had the moistest soils (range 61-100%), then the Plugs and Seeds and Plugs Only treatments at 7-years Hay field (range 38-100%). Next were the Plugs Only and Seeds Only treatments at Over 30-year Old Field (range 43-65%). The soil moisture at the Plugs and Seeds treatment at the Over 30-year Old Field were not significantly different than the Seeds Only at Annual Crop Rotation, but significantly moister soils than the

Plugs Only and Plugs and Seeds treatments at Annual Crop Rotation. The Seeds Only treatment at Annual Crop Rotation was not significantly different than Plugs Only at Annual Crop Rotation but significantly moister than soils at Plugs and Seed at Annual Crop Rotation. There was no significant difference between soil moisture between Plugs Only and Plugs and Seeds in Annual Crop Rotation field.

Soil - pH levels

Mann-Whitney U tests indicated that Annual Crop Rotation (Field 5) had the highest pH, then Over 30-year Old Field (Field 1; only 1P and 1PS), then 7-years Hay (Field 2; including 1S; Figure 4-17).

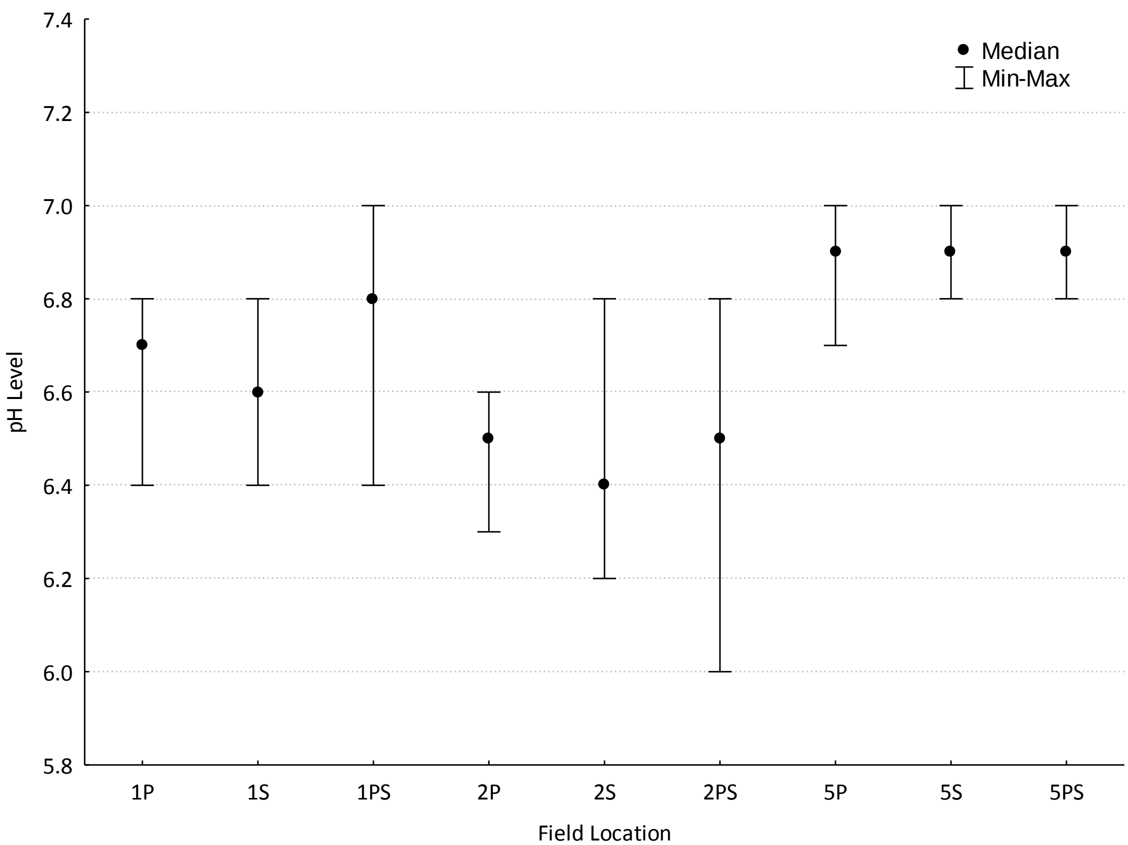

Figure 4-17: pH levels with median and min-max values for the 9 treatments. Treatments are listed with P = Plant Plugs Only, S = Plant Seeds Only, PS = Plant Plugs and Seeds. The numbers indicate Field 1 (Over 30-year Old Field), Field 2 (7-years Hay field) and Field 5 (Annual Crop Rotation).

Annual Crop Rotation had the highest pH levels of all treatments (range 6.7-7.0) and was not significantly different from one another. Over 30-year Old Field had the next highest pH levels at the Plugs treatment and Plugs and Seeds treatment (range 6.4-6.8). 7-years Hay field including treatment 1S had the lowest pH levels (range 6.0-6.8).

Soil - Nutrient levels

Mann-Whitney U indicated that the nitrate-nitrogen levels were lower at Field 5 (Annual Crop Rotation) than Fields 1 (Over 30-year Old Field) and Field 2 (7-years Hay; Figure 4-18).

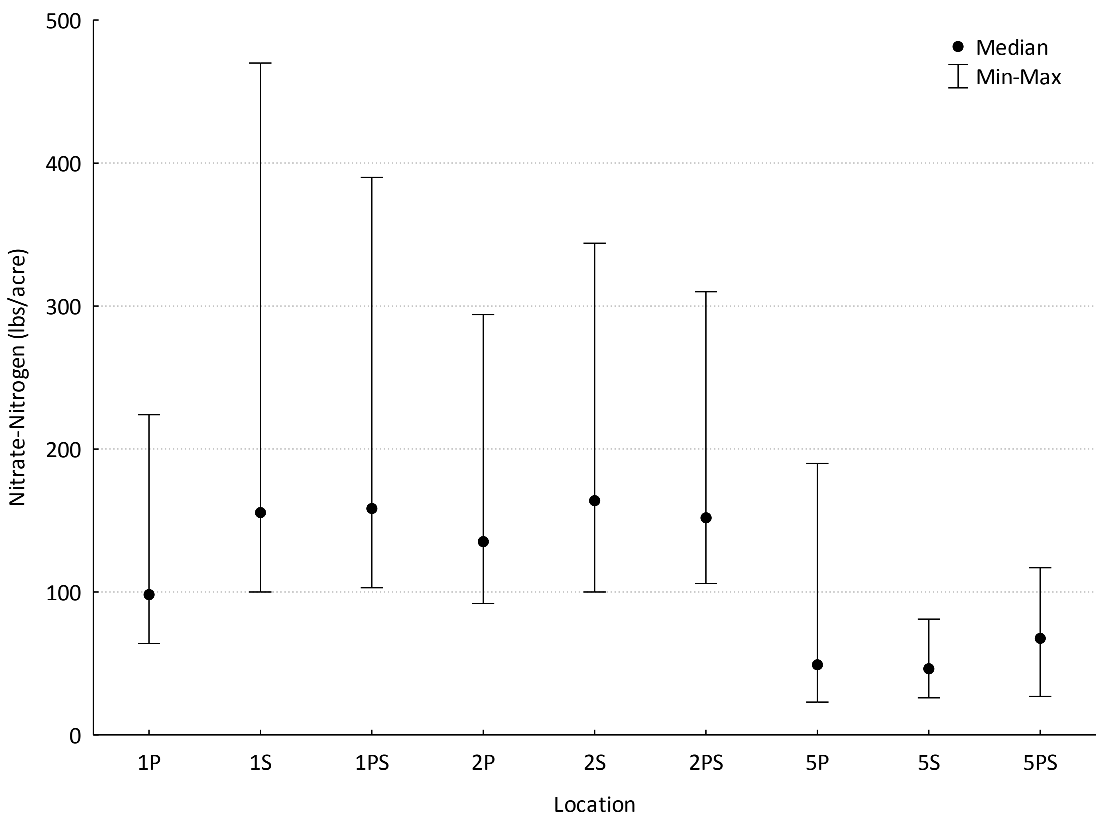

Figure 4-18: Nutrient levels of nitrate-nitrogen at the three field locations in Boyne Valley Provincial Park. Samples were collected October 2010. Treatments are listed with P = Plant Plugs Only, S = Plant Seeds Only, PS = Plant Plugs and Seeds. The numbers indicate Field 1 (Over 30-year Old Field), Field 2 (7-years Hay field) and Field 5 (Annual Crop Rotation).

The lowest nitrate-nitrogen (N) was at the Seeds Only and Plants Only at Annual Crop Rotation (range 23-190 lbs/acre). Higher N was the Plants Only and Plants and Seeds which were not significantly different at Annual Crop Rotation. The Plants Only at the Over 30-year Old Field was higher than all the treatments at Annual Crop Rotation, and lower than the rest of the treatments. All the rest of the treatments were the highest N levels of the experiment (range 99-470 lbs/acre) but varied among themselves in significance levels.

The Mann-Whitney U indicated that Annual Crop Rotation had the highest phosphorus compared to the Over 30-year Old Field and 7-years Hay field (Figure 4-19).

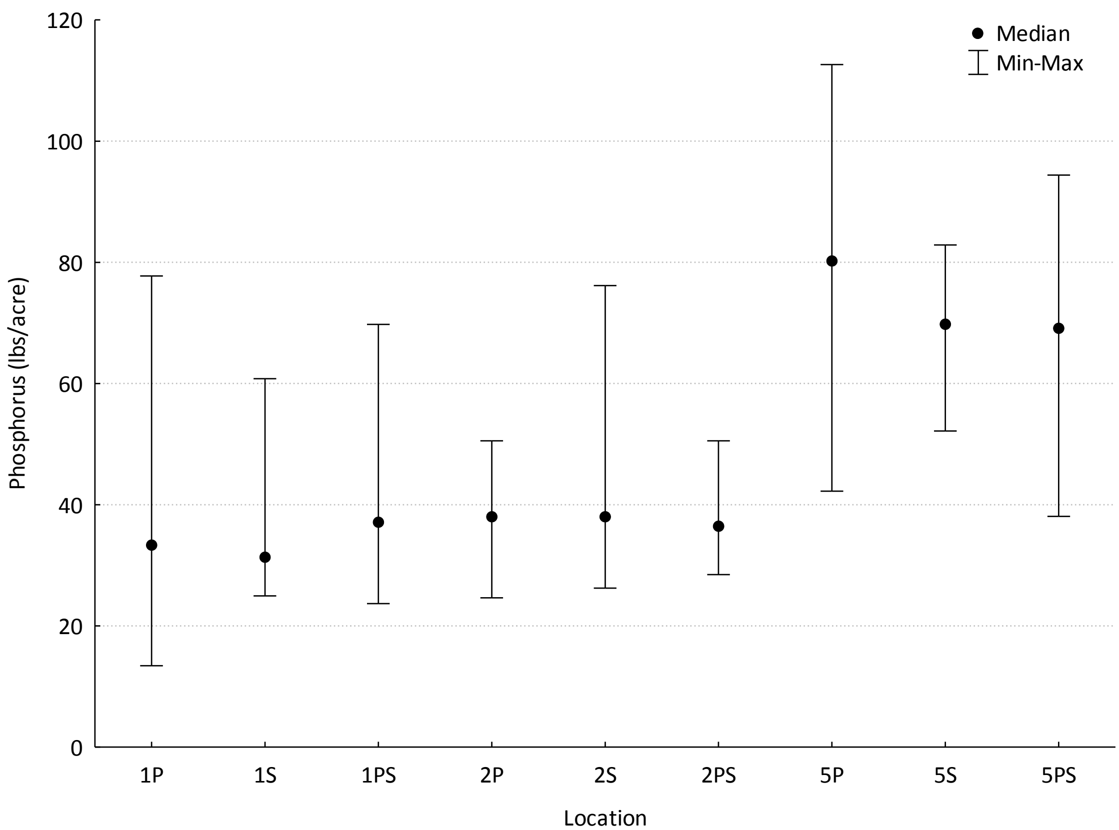

Figure 4-19: Nutrient levels of phosphorus at the three field locations in Boyne Valley Provincial Park. Samples were collected October 2010. Treatments are listed with P = Plant Plugs Only, S = Plant Seeds Only, PS = Plant Plugs and Seeds. The numbers indicate Field 1 (Over 30-year Old Field), Field 2 (7-years Hay field) and Field 5 (Annual Crop Rotation).

The Plugs Only treatment at the Annual Crop Rotation had the highest levels of phosphorus (range 42.2-112.64 lbs/acre) with both Seeds Only and Plant Plugs and Seeds second highest (range 38.8-94.4 lbs/acre). The phosphorus levels at the Over 30-year Old Field and the 7-years Hay field were not significantly different from one another (range: 13.44-77.76 lbs/acre) except Seeds Only at Field 2 was significantly higher than Plugs Only at the Over 30-year Old Field.

Mann-Whitney U test indicated that potassium at the Over 30-year Old Field was highest, then Annual Crop Rotation, and the 7-years Hay field had the lowest levels of potassium (Figure 4-20).

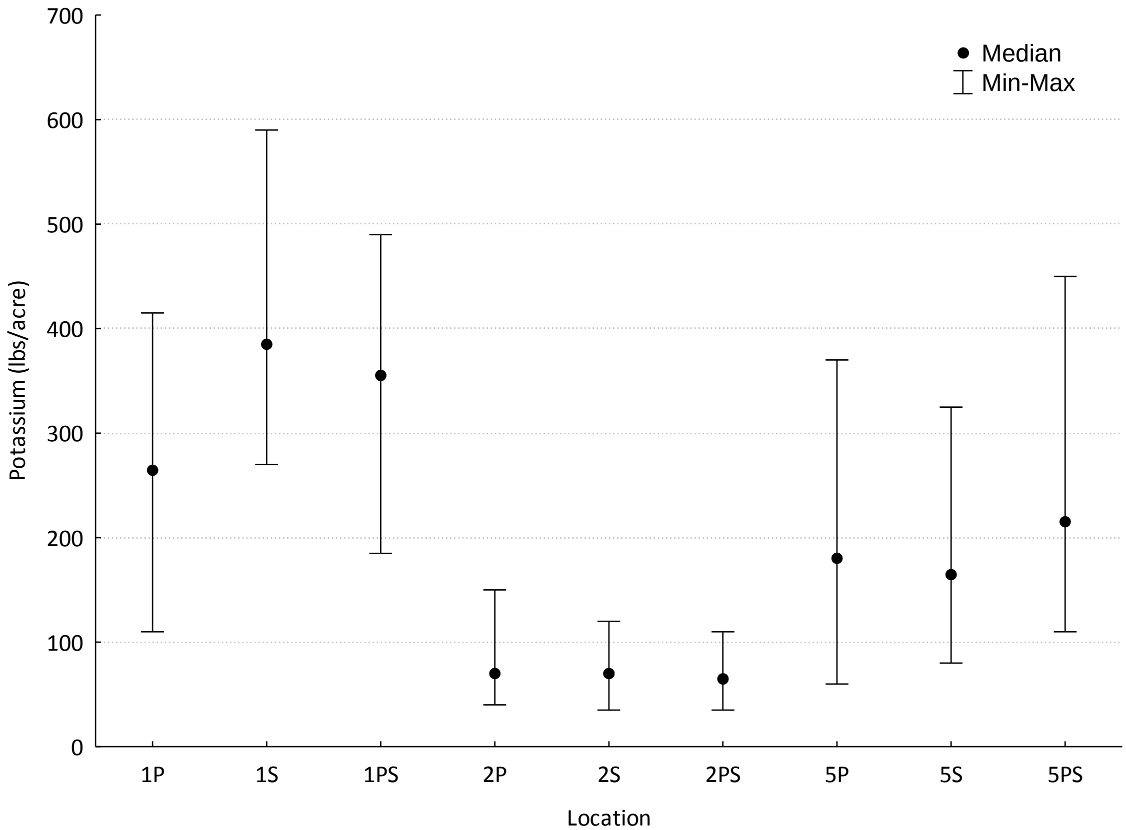

Figure 4-20: Nutrient levels of potassium at the three field locations in Boyne Valley Provincial Park. Samples were collected October 2010. Treatments are listed with P = Plant Plugs Only, S = Plant Seeds Only, PS = Plant Plugs and Seeds. The numbers indicate Field 1 (Over 30-year Old Field), Field 2 (7-years Hay field) and Field 5 (Annual Crop Rotation).

Seeds Only and Plant Plugs and Seeds at the Over 30-year Old Field had the highest level of potassium (range 185-590 lbs/acre) compared to the other transects. Next was Plugs Only at the Over 30-year Old Field and Plant Plugs and Seeds at the Annual Crop Rotation. Significantly lower was the potassium levels (60-450 lbs/acres) at the transects at Annual Crop Rotation. All the transects at the 7-years Hay field had significantly lower potassium levels (35-150 lbs/acre) than the other field locations.

Discussion

While one must be cautious about projecting trajectories and success based on early results (e.g. Anand and Desroches 2004), my initial recommendations based on survivorship and growth for the first year after planting would be to use plant plugs for *E. trachycaulus* ssp. *trachycaulus* and plant plugs, seeds or combination of plant plugs and seeds for *M. fistulosa* and *P. hirsutus*. Given that planting seeds are much less expensive and less laborious than planting plant plugs, I would recommend using seeds for *M. fistulosa* and *P. hirsutus* and depending on the budget, add plant plugs for these two species for aesthetic and promoting new growth (flowering the first year after planting promoting future spreading of the species).

Plant growth (leaf area, spread and plant height) was greatest overall for all species at the Over 30-year Old Field location. Other mechanism than soil nutrients, moisture or pH level tested in this experiment are likely contributors to the plant growth measured. Further research is necessary. As expected, plant growth was greater for plant plugs than seeds, which as above would add to the aesthetics of the restoration area and biomass of a ground cover the first year after planting. All except *S. cryptandrus* flowered the first year after planting if planted from plugs and none of the plants from seeds flowered in the first year.

The difference between the Soils of Ontario (2011) classification and what was found in this study was likely topographical differences. The locations of the plots for the Annual Crop Rotation field were on a slope, creating higher drainage making the soils drier. The 7-years Hay field was at the bottom of a hill where drainage water collected making the soils wetter in this location longer than the other locations. The Over 30-year Old Field was in a flat area making the soils intermediately moist compared to the other two sites.

Danthonia spicata and *S. cryptandrus* yielded a low average of at most six survivors and two survivors, respectively, at all treatments making them poor candidates for a ground cover the first year after planting. Poor seedling survivorship of *D. spicata* may have been caused by unfavorable habitat conditions of the area (Scheiner 1988). The initial successional stage is known to effect seedling survivorship of *D. spicata* (Scheiner 1988); however, with all treatments being tilled, tarped and re-tilled, it is unlikely the successional stage caused poor survivorship. Although they did not grow in this experiment, both *D. spicata* and *S. cryptandrus* are known to have the ability to have long seed life in the soil (Goss 1924; Livingston and Allessio 1968; Abrams and Dickman 1984) and may grow in the following years. This was the case in the seed treatment at the Over 30-year Old Field in this study where none of the seeds germinated the first year but grew the second year after planting. Given the potential of their long seed life and new seedlings growing in the second year after planting, I would recommend adding *D. spicata* to the seed mix in the initial planting to increase the biodiversity of native grasses for the future years. One thing to note is that *Phleum pratense* was present in all three fields, which is known to reduce the seed set in the chasmogamous flowers of *D. spicata* (Murphy 2000) via pollen allelopathy. If this mechanism was present in my study sites, there can be a requirement for continued addition of seeds instead of relying on spread through the plant itself. Given the widespread nature of allelopathic pollen in *D. spicata* (Murphy 2000), it is like that this will be borne out.

Danthonia spicata had the best survivorship on the driest site (Annual Crop Rotation) which is consistent with other studies that concluded that this species is generally found on well-drained soils (Darbyshire and Cayouette 1989; Gleason and Conquist 1991) and has reduced survivorship with increased soil moisture (Reznicek and Maycock 1983). Substrate pH does not seem to impact this species (Darbyshire and Cayouette 1989), but contrary to this, Baker and Nestor (1979) found that *D. spicata* has been shown to increase with a decrease in pH level. This was not tested in this experiment as the pH only ranged between 6.0 and 7.0. A decrease in potassium and phosphorous was shown to increase survivorship (Baker and Nestor 1979); however, with such low survivorship numbers for *D. spicata*, I was not able to extract definitive conclusions from this experiment. Low nitrogen and phosphorus are known to restrict the growth of *D. spicata* (Hardy 1989); however, no pattern could be drawn from this study correlation nutrients and survivorship.

Elymus trachycaulus ssp. *trachycaulus* had a high survivorship when using plant plugs. With *E. trachycaulus* ssp. *trachycaulus* as an early pioneer in primary and secondary succession (Howard 1992), the high seed production and vegetative production of *E. trachycaulus* ssp. *trachycaulus* (Hardy 1989; Howard 1992) will make a good initial ground cover species in restoration at Boyne Valley Provincial Park. *Elymus trachycaulus* ssp. *trachycaulus* can dominate in the early stages with its high seed production, but decreases in later successional stages (but continue to persist; Howard 1992). Seeds of *E. trachycaulus* ssp. *trachycaulus* are not long lived in the soil and are known to only last for three to six years in the soil (Howard 1992).

The highest survivorship for *E. trachycaulus* ssp. *trachycaulus* in this study was on soil moisture between 30-60%. This is similar with Howard's (1992) study that found *E. trachycaulus* ssp. *trachycaulus* can grow in dry to moist conditions, medium-textured soil, and does best on sandy loam soils. Soil pH in this study only ranged between 6.0-7.0 although *E. trachycaulus* ssp. *trachycaulus* has a high salt tolerance (Looman 1982; Howard 1992) with pH levels from moderately acid to alkaline but has been found in soils with a pH as high as 8.9 (Hardy 1989; Howard 1992). Nutrient levels are known to effect growth of *E. trachycaulus* ssp. *trachycaulus* with the highest sensitivity to potassium deficiency causing reduced plant growth, leaf scorching (turn ash-white and papery and finally drop off; Hardy 1989). We did see a lower survivorship at the 7-years Hay field, which had the lowest potassium level (range 35-150 lbs/acre) of the three sites; however, other factors such as high soil moisture may also have stunted the survivorship at this location.

Both flowering plants *M. fistulosa* and *P. hirsutus* had a high survivorship in all treatments the first year after planting. For the second year after planting, of the five species planted, both *M. fistulosa* and *P. hirsutus* were the only species that did not change in survivorship (percentage) between the first and the second year. *Monarda fistulosa* is known to have high survivorship with transplants of eight week seedlings (May-June) showing flowers emerging in the 2^{nd} year (Nuzzo 1978) and after a winter seeding (Hitchmough et al. 2004). Tilling the land may have improved the survivorship of *M. fistulosa* as competition from established neighbours is known to control seedling emergence (Greiling and Kichanan 2002). High survivorship of *P. hirsutus* may be attributed to the wide variety of soil conditions it can grow on (Clements et al. 2002). *Penstemon hirsutus* can grow on a wide variety of substrates with a range of fertilities and pH levels (range 4.5–7.65; Clements et al. 2002). Their study indicated that *P. hirsutus* grew best in soil of high phosphorus (2247 kg/ha) and worst in black shale soil (pH=3.37; Clements et al. 2002). Although the pH level for all sites were significantly different, the pH level ranged from 6.0-7.0 and no pattern could be drawn from this study relating pH levels and survivorship. Similarly, no pattern could be drawn relating soil nutrients and survivorship.

Conclusion

Recommendations based on survivorship and growth for the first year after planting would be to use plant plugs for *E. trachycaulus* ssp. *trachycaulus* and seeds for *M. fistulosa* and *P. hirsutus*. Depending on the budget, I would add plant plugs for *M. fistulosa* and *P. hirsutus* for aesthetic and promoting new growth (flowering the first year after planting promoting future spreading of the species).

Continual monitoring of the five plants species is necessary to understand the long-term survivorship and growth of these species. Future studies should include adding more species to increase the diversity of the restoration, which will increase the functional and response diversity of the system. Longer-termed research will help to better understand and potentially predict succession for meadow restoration in Boyne Valley Provincial Park.

APPENDIX A: List of species at risk (SAR) in Ontario that use prairie and/or meadow ecosystems for foraging or habitat use (OMNR 2013).

Taxonomy	Common Name	Scientific Name	OMNR Status	Grassland Use
Amphibians	Eastern Tiger Salamander	*Ambystoma tigrinum*	Extirpated	Habitat
Birds	Barn Owl	*Tyto alba*	Endangered	Foraging
Birds	Bobolink	*Dolichonyx oryzivorus*	Threatened	Habitat
Birds	Eastern Meadowlark	*Sturnella magna*	Threatened	Habitat
Birds	Golden Eagle	*Aquila chrysaetos*	Endangered	Foraging
Birds	Golden-winged Warbler	*Vermivora chrysoptera*	Special Concern	Habitat (forest edge)
Birds	Greater Prairie-Chicken	*Tympanuchus cupido*	Extirpated	Habitat
Birds	Henslow’s Sparrow	*Ammodramus henslowii*	Endangered	Habitat
Birds	Loggerhead Shrike	*Lanius ludovicianus*	Endangered	Habitat
Birds	Northern Bobwhite	*Colinus virginianus*	Endangered	Habitat (forest edge)
Birds	Short-eared Owl	*Asio flammeus*	Special Concern	Habitat
Insects	Aweme Borer Moth	*Papaipema aweme*	Endangered	Habitat
Insects	Eastern Persius Duskywing	*Erynnis persius persius*	Extirpated	Habitat
Insects	Monarch	*Danaus plexippus*	Special Concern	Habitat
Mammals	Eastern Mole	*Scalopus aquaticus*	Special Concern	Partial Habitat
Plants	Bird’s-foot Violet	*Viola pedata*	Endangered	Habitat
Plants	Climbing Prairie Rose	*Rosa setigera*	Special Concern	Habitat
Plants	Colicroot	*Aletris farinosa*	Threatened	Habitat

Taxonomy	Common Name	Scientific Name	OMNR Status	Grassland Use
Plants	Dense Blazing Star	*Liatris spicata*	Threatened	Habitat
Plants	Gattinger's Agalinis	*Agalinis gattingeri*	Endangered	Habitat
Plants	Hill's Thistle	*Cirsium hillii*	Threatened	Habitat
Plants	Illinois Tick-trefoil	*Desmodium illinoense*	Extirpated	Habitat
Plants	Pink Milkwort	*Polygala incarnata*	Endangered	Habitat
Plants	Purple Twayblade	*Liparis liliifolia*	Threatened	Habitat
Plants	Riddell's Goldenrod	*Solidago riddellii*	Special Concern	Habitat
Plants	Showy Goldenrod (Boreal population)	*Solidago speciosa*	Threatened	Habitat
Plants	Showy Goldenrod (Great Lakes Plains)	*Solidago speciosa*	Endangered	Habitat
Plants	Skinner's Agalinis	*Agalinis skinneriana*	Endangered	Habitat
Plants	Slender Bush-clover	*Lespedeza virginica*	Endangered	Habitat
Plants	Virginia Goat's-rue	*Tephrosia virginiana*	Endangered	Habitat
Plants	Western Silvery Aster	*Symphyotrichum sericeum*	Endangered	Habitat
Plants	White Prairie Gentian	*Gentiana alba*	Endangered	Habitat
Plants	Willowleaf Aster	*Symphyotrichum praealtum*	Threatened	Habitat
Reptiles	Blue Racer	*Coluber constrictor foxii*	Endangered	Habitat
Reptiles	Butler's Gartersnake	*Thamnophis butleri*	Endangered	Habitat
Reptiles	Milksnake	*Lampropeltis triangulum*	Special Concern	Partial Habitat

Chapter 5. Synthesis: Restoration recommendations for retired agriculture fields at Boyne Valley Provincial Park

Introduction

The research into meadow restoration in Boyne Valley Provincial Park presented in this thesis constitutes both a pilot and a case study. I aimed to integrate two main concepts: ecological restoration and landscape preferences (Figure 1-2 from Chapter 1).

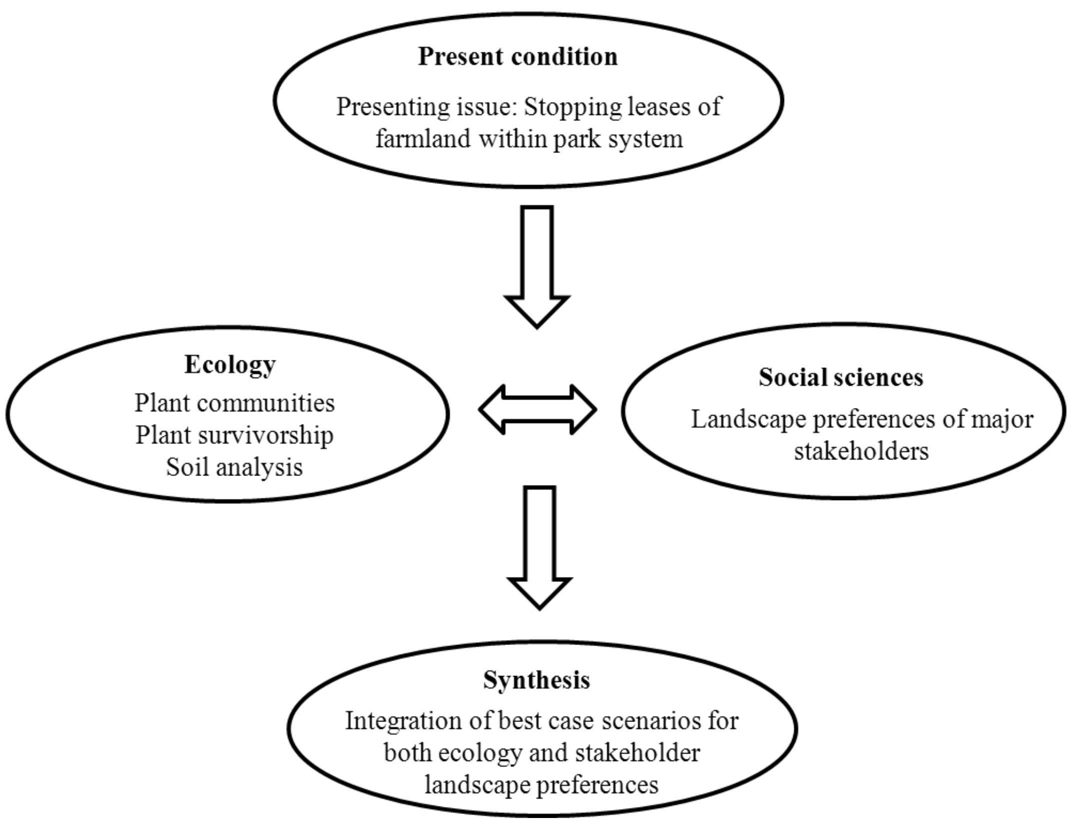

Figure 1-2: Scheme of integrating social and ecological disciplines for restoration at Boyne Valley Provincial Park. (Chapter 1)

The synthesis part of Figure 1-2 was an iterative process in which the best cast scenarios were drawn from both the ecological and social aspects to make a recommendation for Ontario Parks. Ecological restoration involving only plantings and habitat management is likely to fail without knowledge of stakeholders' landscape preference. Restoring land without understanding the state of the soil and testing plant species could lead to very costly mistakes.

Integration of Social and Ecological Research at Boyne Valley Provincial Park

Using novel ecosystems as a framework for restoration will allow Parks' managers to better understand the available restoration choices (Hulvey et al. 2013). For example, historical references have changed within the Park - farmland borders Boyne Valley Provincial Park creating the need for farmers and Parks personnel to work together. In addition, species composition has changed with non-native species dominating the seedbank and native meadow species under-represented in the area. Acknowledging that we are dealing with a novel ecosystem, a certain amount of uncertainty is expected and continued monitoring of the system is necessary.

The research in this thesis explored how to integrate social and ecological aspects of restoration together. My research built on the need for an integrated approach surrounding restoration goals. The extent my research integrated social and ecological aspects is similar to Hochtl et al. (2006) in that the integration comes after each discipline was investigated. No new methodology was devised, and perhaps that should not be a goal of integration. One of the novel aspects of my research was the use of photo-elicitation to explore the social aspect of restoration. Photo-elicitation has been used extensively to determine people's landscape preferences (see Chapter 1 for more detail); however, it has not been used to my knowledge in conjunction with restoration ecology. Using photo-elicitation coupled with semi-structured interviews provided an avenue to engage stakeholders (Glover et al. 2008) and bridge the communication barrier between researcher and stakeholders. Three themes were suggested from the interviews with stakeholders at Boyne Valley Provincial Park: 1) aesthetics; 2) stakeholder familiarity with Boyne Valley Provincial Park landscape and native species; and 3) functionality (Ontario Parks' Mandate regulations, workload for maintenance, and integration of farmland and Parks' land).

Integrating the three themes listed above with the results from the ecological research, the restoration recommendations for Ontario Parks' include restoring with native species containing various wildflowers and involving stakeholders in the entire planning process. Given the novelty of meadow ecosystems in the landscape, it may be best to restore lands in smaller increments rather than the entire 122 ha of land at once. This researched has initiated a basis for conversation among stakeholders which will need to be continued throughout the management of the land.

Although more heavily situated in the biophysical side of research, my research still shows the type or resistance Ontario Parks may face. The same prescription for management applies - farmers need to be involved throughout the restoration process.

Restoration ecology and Transdisciplinarity

Restoration ecology inherently links social and ecological disciplines together although in practice, the ecological side tends to be the focus. My research, through the use of novel ecosystems as a framework, adds to the field of restoration ecology by integrating the social and ecological disciplines as an iterative decision-making process. In deciding ecological restoration goals, personal values, and our concept of 'good' restoration influence our choices as well as facing challenges of societal expectation (Higgs 2003; Hobbs et al. 2004; Hobbs 2007; Temperton 2007). More research is needed on the integration of social aspect relating to the ecological aspect of restoration is necessary (Gobster and Hull 2000; Higgs 2003; Hobbs 2007).

It has been proposed by some authors that environmental management may be best achieved using a transdisciplinary approach (e.g. Hochtl et al. 2006). This is because of the type of research questions that are being asked - the complexity of landscape change and the interrelatedness of natural and human systems require researchers to take an integrative approach (Slocombe 1993; Freemark 1995; Pickett et al. 1999; Naveh 2000; Fry 2001; Kinzig 2001; Pickett et al. 2004; Naveh 2005; Knight et al. 2008; Nassauer and Opdam 2008; Tress and Tress 2009).

One issue that seems simple to tackle – yet vexing to resolve – is the confusion of terminology. Terms such as interdisciplinary and transdisciplinary are sometimes used interchangeably (Lele and Norgaard 2005) with both terms defined as research that involves more than one unrelated academic discipline (Tress et al. 2009b). A useful means of separating the term transdisciplinary is to define it as involving non-academic participants such as land managers, user groups and the general public to create new knowledge (Tress et al. 2009b). This is how I applied it when describing my research because it explicitly involves these communities of practice. I did find that additional attention was needed for me to attempt to integrate different academic traditions with the lack of common terminology – this is congruent with the findings of Tress et al. (2009a).

A more substantive issue is the lack of a well-defined and cohesive conceptual, theoretical, and methodological framework surrounding transdisciplinary research. Much of this stems from four fundamental barriers of working in more than one discipline (LeLe and Norgaard 2005). The different values associated with the different types of inquiry such as the questions asked, theoretical positions, variables studied and style of research used in each discipline. Next, the use of explanatory models and underlying assumptions in each discipline differs. Thirdly, each discipline uses specific methods with fundamental assumptions associated with the methods. Lastly, the way society influences research outside of one's discipline. A better understanding of these issues is the first step in bridging the various divide in integrating different disciplines in addressing complex environmental problems (Lele and Norgaard 2005).

Several studies have made advances using a mixed-methods approach in efforts to lead towards a transdisciplinary approach. For example, understanding local resident's perception of land use changes that were going to occur with the restoration of the floodplain river-systems in Europe through questionnaires and incorporating the opinions into management plans for restoration (Schaich 2009). To go one step farther with integration, different ecological restoration scenarios should have been tested to incorporate the best ecological results and have these presented to the local residents. Dahdouh-Guebas and Koedam (2008) point to gathering data from different retrospective research approaches to better understand mangrove development. Examples include collecting data from above-ground fieldwork observation, landscape (repeat) photography, substrate cores and historic archives to better predict mangrove development. This was more about how and why to integrate different disciplines but did not explicitly carry-out the experiment and integration process.

One study that was similar to my approach of integrating social and ecological discipline was Hocht et al. (2006) research in the Piedmont Alps. They proposed a five step strategy involving defining the problem definition, comprehension of the problem, analysis of the problem, treatment of different disciplinary areas, and integration of results from disciplinary areas to achieve overlapping results (Hocht et al. 2006). Their problem definition consisted of understanding the different perceptions of the landscape from the locals to the scientific community and defining the core problem. To research the problem (comprehension of the problem), five questions were devised consisting of vegetation ecology, historical geography and social sciences. To analyse the problem, they chose three disciplinary areas – historical, ecological and socio-empirical surveys – that were subordinated to the entire problem definition but still intended to answer the core questions. The treatment of each disciplinary areas meant they simultaneously assessed two disciplinary areas at the same time, terming this reciprocal reference. The last step, which was the true integration of social and ecological disciplines, came from the fifth question on strategies of a sustainable future that was derived from the different results. From the transdisciplinary approach, they concluded that a realistic scenario would be the revitalisation of at least some of the abandoned areas and development of the still existing cultivations; this approach would conserve biodiversity in the area and strengthen local socioeconomic development (Hocht et al. 2006).

Effectively, many experiences and publications appear to achieve some form of integration in research - crossing disciplinary boundaries or at least stepping out of one discipline and using others. The main reflection is whether even steps towards using multiple disciplines and steps towards their integration is important in terms of an effective “melange” of frameworks and whether a transdisciplinary approach is achievable in anything but name. Integration comes down to a decision-making approach by which a person or team of people decide how to and how much they want to mesh social goals and biophysical data. For example, environmental impact assessments at the municipal, provincial and federal levels in Canada generally require letters of information with the opportunity for discussion with Aboriginal people in the area at a minimum, but the extent of social inquiry and the integration of the social aspect into the environmental impact assessment report are dealt on a case-by-case situation.

Framing this research with novel ecosystems concepts helped to integrate the ecological and social aspects of restoration. On reflection, this is an important advance and contribution because a more effective management of our lands will require integration of disciplines (For example, Freemark 1995; Pickett et al. 1999; Fry 2001; Kinzig 2001; Knight et al. 2008; Nassauer and Opdam 2008). The path towards true integration of disciplines - much less a transdisciplinary framework is a steep slope. A mixed-methods approach that moves towards the path of transdisciplinary is important but the ideal framework is tantalizingly out of grasp for now.

Social-ecological Resilience as a Long-Term Goal

Social-ecological resilience provides a long-term goal for both the social and ecological aspects of restoration; however, it is not without issues. The lack of integration between social and ecological research (see Folke 2006) was apparent when using it as a long-term goal for restoration research. For example, how decisions are made to account for social needs or aspirations such as landscape preferences for the Parks' land. Compounding these issues, how to consider ecological dynamics in terms of multi-generational impacts and equity such as soil degradation from many years of farming with continued farming surrounding the restoration.

Resilience has changed and been redefined by various scientific disciplines (Brand and Jax 2007) since Holling's seminal paper in 1973 and should be expected to continue to evolve in the future. One direction of improvement for the future of resilience concerns the heavy terminology (or jargon) used when discussing resilient ideas. Walker and Salt (2006 and 2012) wrote two books trying to eliminate the heavy terminology that comes with understanding resilience. The resilience perspective intends to help explain, understand and manage the dynamics of the landscape; however, if only academics and a handful of natural resource managers understand the concept of resilience, its application is limited. With books by Walker and Salt (2006 and 2012), that are designed to be read by anyone interested in the topic, and the Resilience Alliance's (2010) workbook "Assessing Resilience in Social-Ecological Systems: workbook for practitioners", resilience may appeal to more practitioners looking for a different perspective.

Recommendations for Restoration Management Plan at Boyne Valley Provincial Park

While this is an early and perhaps more exploratory study, I aimed to build recommendations for Ontario Parks' restoration management plan for the first few years after they cease the leases for agriculture practices within Ontario Parks' boundaries in December 2015. The research is focused in Boyne Valley Provincial Park and recognises that future research on various park locations will be required before generalization of recommendations can be made. My recommendation is based on an integration of the social and ecological aspects while keeping in mind the long-term social-ecological resilience goal. Limitations to this research include the unknown future trajectory of the restoration. Future research and adaptive management will be the key to understanding longer-termed restoration research and adapting to unknown and unforeseen trajectories and events that may occur. This research was carried out in one park and before generality can be stated, similar research needs to be carried out on more parks with different land-use history.

Considering this is a novel ecosystem, both in that the landscape is unfamiliar in Boyne Valley Provincial park and as a system incorporating changed biotic and abiotic inputs (sensu Hobbs et al. 2006), I recommend implementing the restoration efforts at a smaller scale to start. The remaining fields should continue to be farmed until restoration can commence or mowed at least four times a year before seeds are formed. Over many years, areas that are seeded with native plants will build a native seed bank which can be transplanted to other areas. This area can act as an on-site nursery for the rest of Boyne Valley Provincial Park. Weed maintenance will have to continue for many years. Open communication should continue between all stakeholders.

For the areas that are going to undergo restoration, soil preparation should include tilling the soil prior to planting is if the land was left abandoned (e.g. old-field). Tilling produced no noticeable difference in the proportion of non-native species at the annual crop rotation site; however, tilling changed the dominant species suggesting tilling may be beneficial depending on the species composition. A plant composition survey should be conducted prior to restoration – more particularly in hay fields - to determine if native meadow species are found. If native meadow species are present (e.g. *Sisyrinchium montanum*) that would not survive tilling, a no-till planting method may be a better option than tilling.

Laying tarpaulin for the growing season was not effective at getting rid of the clonal species in this experiment. This method was also extremely time consuming and laborious to cover 255 plots. I suggest only laying tarps for small areas to target particularly aggressive invasive species, if necessary.

Tilling and using planting plugs were most beneficial at the Over 30-year Old Field location while having little effect in the 7-year hay or the annual crop rotation fields. Recommendations to increase native richness towards a meadow ecosystem in all locations would be to plant a combination of established seedlings and seeds.

Planting native species is essential to restoring abandoned agricultural fields to a meadow ecosystem at Boyne Valley Provincial Park. Acknowledging these are early results, my initial recommendation based on survivorship and growth for the first year after planting would be to use plant plugs for *Elymus trachycaulus* ssp. *trachycaulus* and a combination of plant plugs and seeds for *Monarda fistulosa* and *Penstemon hirsutus*. Future studies should incorporate more grasses and wildflowers to increase the biodiversity while choosing flowers that bloom at different times. Additionally, pilot studies should be completed at all Ontario Park locations where agriculture leases are ending to develop restoration methodologies that are applicable across Ontario. Information on each of the species that are to be planted should be distributed to the farmers that border the parks boundaries. This information should include at minimum the species life history, dispersal mechanisms, and a photograph.

Future Research

Ontario Parks has reached beyond their commitment to their mandate of ecological integrity in the *Provincial Parks and Conservation Reserves Act, 2006* - which focuses on the ecological well-being of the land – by following the recommendations from this research; namely by integrating both social and ecological disciplines towards a more resilient restoration endeavor.

There is the issue of scaling from one park to across all of Ontario Parks land and trying to generalize. On the biophysical side, there is likely little difference in farming technique across the board. In terms of social perspective, farmer’s concerns may include litter, pests, increased liability, farm restrictions and loss of profit (Hammond 2002). Similar to the issue in Boyne Valley Provincial Park, weeds are a common problem for farmers with herbicide being the primary solution for weed management (Wyse 1994). Along with weeds, pests invading from the neighbouring land without herbicide (park land or organic farming) use may cause some concern for farmers. Gosme et al. (2012) showed that in the short term, organic fields with low disease pressure did not increase the pest problem in neighbouring fields; although, more research is needed on a landscape scale to determine the effects in terms of pest populations of organic farming on neighbouring fields. Continued research involving stakeholders is a must.

The research in this thesis outlines initial restoration efforts to guide restoration recommendations for the first year after land abandonment. Much longer-termed research is necessary to understand community dynamics and potential recovery of system (Hobbs and Norton 1996; Anand and Desrochers 2004). Long-term studies of underlying ecological mechanism are needed for predicting ecosystem recovery. Some of the longer-termed restoration studies include a 17-year study that indicted different trajectories for vegetation change for each of the different treatments on former grassland (Pywell et al. 2011). A 22-year study on old fields in southern Ontario showed differences in vegetation after hayfield abandonment and ploughing (Crowder et al. 2007). Although these are some of the longer restoration studies, long-term in terms of meadow ecosystem should be at minimum 80 years to span the succession from bare soil to forest.

To improve the ecological resilience of the restoration, biodiversity may be crucial (MacDougall et al. 2013). Additional plantings will need to be incorporated into the longer-termed research. As new information is available to Ontario Parks, the restoration management plan should be updated to reflect the changes. Restoration success on a small-scale includes the native species proportion, mostly planted species to be higher than the non-native species proportion. Over the long-term, the meaning of restoration success will be the recovery of meadow ecosystems without assistance within Ontario Park. One thing to keep in mind is that restoration takes time and there is frequently a time lag between restoration and change to the environment (Woodcock et al. 2012). Given the scale of this research, establishment of individual species will be between 1-2 years; however, the time frame for establishment of a meadow community requires more research. Succession and invasion of shrubs and trees will potentially occur within five to ten years of restoration efforts. The presence and absence of shrubs and trees should be researched to allow for longer-termed succession studies of meadows to forests. Depending on the scale of meadow restoration completed within Ontario Parks, succession to a forest may be considered or maintenance of the area as a meadow may provide higher ecological integrity for Ontario Parks. To build a general recommendation for Ontario Parks that truly integrates social and ecological disciplines, multiple studies across all Parks on a larger scale need to be created.

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