

DISSERTATION

**BIOLOGICAL CONTROL AFFECTS NATIVE VEGETATION AND
RECOVERY POTENTIAL IN THEODORE ROOSEVELT NATIONAL PARK,
NORTH DAKOTA**

Submitted by

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In partial fulfillment of the requirements

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY JULIE ANN LAUFMANN ENTITLED BIOLOGICAL CONTROL OF LEAFY SPURGE AFFECTS NATIVE VEGETATION RECOVERY POTENTIAL IN THEODORE ROOSEVELT NATIONAL PARK, NORTH DAKOTA BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

BIOLOGICAL CONTROL AFFECTS NATIVE VEGETATION AND RECOVERY POTENTIAL IN THEODORE ROOSEVELT NATIONAL PARK, NORTH DAKOTA

This study evaluated native vegetation recovery in areas infested with leafy spurge (*Euphorbia esula* L.) and treated with the bio-control agent *Apthona* spp. and examined in-situ seed bank potential to predict recovery of native species. Extant vegetation and seed bank species richness, diversity, composition and community similarities were evaluated in leafy spurge infested, infested leafy spurge sites that received bio-control treatment, and non-infested sites in three vegetation associations in the South Unit of Theodore Roosevelt National Park, North Dakota. The Modified Whitaker sampling method was used to obtain extant species richness and relative cover. Seed bank sampling plots (15 m x 15 m) were centered in the Modified Whitaker plots. Similarity and dissimilarity analyses compared species assemblages among non-infested, infested and bio-control sites in extant vegetation, seed banks, and between extant vegetation and seed bank species.

No reductions in extant species richness or diversity were observed between non-infested, infested, and bio-control sites across the three vegetation associations ($p \geq 0.05$). Extant vegetation forb component was reduced by 13-30% in bio-control sites compared to non-infested sites. Eighty-nine percent of extant species affected by leafy spurge infestation were present in bio-control sites. Similarity coefficients between extant vegetation and seed bank species were low, reflecting heterogeneity of badlands topography. Seed was present in bio-control and infested sites for 50 to 75% of

commonly occurring extant vegetation species documented in non-infested sites across the vegetation associations. Mean leafy spurge seed densities in infested sites ranged between 447 to 931 seed/m² in and 164 to 724 seed/m² in bio-control sites across vegetation associations. Leafy spurge seed densities in infested sites were not significantly different than those observed in bio-control sites. Non-native species seed densities other than leafy spurge were similar among sites.

Vegetation previously infested by leafy spurge and treated with bio-control agents are recovering in the Park and will continue to improve based on the presence of seed bank species. Future monitoring of impacted areas is necessary to validate results to ensure that leafy spurge does not re-establish in communities because of high seed densities of leafy spurge seed in bio-control sites.

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TABLE OF CONTENTS

ABSTRACT OF DISSERTATION.....	iii
ACKNOWLEDGEMENTS.....	v
TABLE OF CONTENTS.....	vii
LIST OF TABLES.....	ix
LIST OF FIGURES.....	xii
CHAPTER I: INTRODUCTION.....	1
Soil Seed Banks.....	5
Scope of this Study.....	7
Objectives and Hypotheses.....	9
CHAPTER II: STUDY AREA AND METHODS.....	10
Study area.....	10
Field Methods.....	14
Seed Bank Identification.....	18
Statistical Analyses.....	20
CHAPTER III: RESULTS.....	24
Resident Vegetation Analyses.....	24
Species Richness and Composition.....	24
Vegetation Association Trends.....	27
Vegetation Association Similarity and Dissimilarity.....	31
Seed Bank Analyses.....	33
Seed Bank Species Richness.....	33
Seed Bank Composition.....	33
Common Seed Bank Species.....	35
The Leafy Spurge Seed Bank and Non-native Species.....	37
Seed Bank Species Similarity.....	41
Extant Species and Seed Bank Species Comparisons.....	41
All Extant Species vs. Seed Bank Species.....	41
Common Extant Species and Seed Bank Species Comparisons.....	43
Extant Species Impacted by Leafy Spurge and Seed Bank Availability.....	46
Extant Vegetation in Non-Infested Sites and Seed Bank Availability in Bio-control and Infested Sites.....	46

CHAPTER IV: DISCUSSION	50
Vegetation	50
Seed Bank/Vegetation.....	54
Richness and Compositional Differences	56
Seed Present in Seed Bank Yet Absent in Vegetation.....	59
Leafy Spurge Seed Bank.....	60
Presence of Non-native Species	61
CHAPTER V: SUMMARY AND CONCLUSIONS.....	63
CHAPTER VI: LITERATURE CITED.....	67
APPENDIX A. Additional Tables and Figures	80
APPENDIX B. Species Key, Data and Statistical Output.....	115

LIST OF TABLES

Table 2.1 Treatment design within three vegetation associations in the South Unit of Theodore Roosevelt National Park, ND.....	15
Table 2.2. Seed bank fractions, sampling dates and field sampling design by vegetation association	18
Table 3.1. Mean species richness of the 100 m ² and 1000 m ² plots within the modification of the Modified Whitaker sampling method and Shannon Wiener diversity indices (H') for non-infested (NI), infested (IF), and bio-control (BC) sites in silver sage, needle and thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Data were collected June, 2002.....	25
Table 3.2. Mean species richness by growth form, standard deviations \pm , and total number of species () in non-infested (NI), infested (IF) and bio-control (BC) sites in three vegetation associations located in the South Unit of Theodore Roosevelt National Park, ND. Weedy species determined by North Dakota state coefficients of conservation (Northern Great Plains Floristic Quality Assessment Panel 2001).	26
Table 3.3. Common and persistent extant vegetation species in silver sage (SS), needle and thread (NT) and green ash draw (GA) vegetation associations within the South Unit of Theodore Roosevelt National Park, ND. Persistent species are species with frequencies of 67% or more within non-infested, infested and bio-control sites (n = 6 for all sites except n = 4 for green ash draw infested sites). Vegetation analyses conducted June, 2002.....	28

Table 3.4. Species affected by leafy spurge infestation in non-infested (NI), infested (IF), and bio-control (BC) sites in silver sage (SS), needle and thread (NT), and green ash draw (GA) vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Common/sensitive species occur at frequencies of 67% or more in non-infested sites, yet were reduced by 50% or more in infested sites. Occasional sensitive species were species that occur within the non-infested sites at frequencies of 34-50% yet were absent in the infested sites. Frequencies were based on 1000 m² plots.....29

Table 3.5. Similarity (*J*) and dissimilarity coefficients (*D_{ij}*) for extant vegetation composition for silver sage, needle and thread and green ash draw vegetation associations for non-infested (N), infested (IF), and bio-control (BC) sites in South Unit of Theodore Roosevelt National Park, ND. Leafy spurge species occurrence and average percent cover were removed from data set. Jaccard's coefficient (*J*) was used for 1000 m² and 100 m² plots and Bray Curtis coefficient (*D_{ij}*) was used for average percent cover. Baseline coefficients reflect the average (dis)similarity among replicates within each site.32

Table 3.6. Mean seed bank richness and standard deviations () for each seed bank fraction for silver sage, green ash draw, and needle and thread vegetation associations within non-infested (NI), infested (IF), and bio-control (BC) sites. Transient seed banks consisted of seedlings germinated from surface litter (collected Sept 2001 = transient late, and June 2002 = transient early) in the South Unit of Theodore Roosevelt National Park, ND. Persistent seed bank consisted of seedlings germinated from soil core samples. Dormant seed bank consisted of remaining un-germinated viable seed from the persistent seed bank.....34

Table 3.7. Mean seed bank richness and standard deviations () by composition in non-infested, infested, and bio-control sites in silver sage, needle and thread and green ash draw vegetation associations located in the South Unit of Theodore Roosevelt National Park, ND. Seed bank species consists of all seeds germinated and identified in a greenhouse emergence study and all remaining ungerminated seeds remaining in soil core samples collected in Sept. 2001 and June 2002.....36

Table 3.8. Percentage of species shared between the extant vegetation and seed banks in non-infested (NI), infested (IF), and bio-control (BC) sites in the silver sage, needle and thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND.....45

Table 3.9. Extant vegetation species affected by leafy spurge infestation and corresponding seed bank plot frequencies and seed densities (seed/m²) in non-infested, infested, and bio-control sites in silver sage, needle and thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND.....47

Table 3.10. Comparison between the number of commonly occurring extant vegetation species (frequency of 67% or more) in the non-infested extant vegetation sites to identical species found in the seed bank in non-infested (NI), infested (IF) and bio-control (BC) sites in the silver sage, needle and thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Mean leafy spurge seed density (seed/m²) is also presented for each site within vegetation associations.49

LIST OF FIGURES

- Figure 2.2. Modification of the Modified Whitaker plot design and seed bank sampling plot area used in this study. Extant species occurrences were recorded (June, 2002) within 1000 m² and 100 m² area and percentage cover by species was recorded for each 0.5 m x 2 m area using Daubenmire cover class determinations (Daubenmire, 1959). Thirty randomly selected seed bank samples (based on a 225 m² grid) consisting of surface material and soil cores (10 cm diameter by 5 cm deep) were collected Sept. 2001 and June 2002.16
- Figure 3.1. Total seed bank mean seed density (seed/m²) of leafy spurge in non-infested (NI), infested (IF) and bio-control (BC) sites in silver sage, needle and thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Mean seed densities consist of the sum of all seed within seed bank fractions (transient, persistent, and dormant) and averaged over the number of plots.39
- Figure 3.2 Mean seed density of leafy spurge in the transient, persistent and dormant seed banks in non-infested (NI), infested (IF) and bio-control (BC) sites in silver sage, needle and thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Transient seed banks consisted of seed present in surface litter collected in late summer of 2001 and early summer of 2002. Persistent and dormant seedbanks represent seed present in soil cores collected in fall of 2001. All dormant seed was tested for viability using tetrazolium (AOSA 2002). Thirty, 5 x 10 cm cores were collected from each plot, n = 6 for all samples except for green ash draw infested plots where n = 4.40

Figure 3.3. Seedbank species occurrences and Jaccard's baseline (BL) and similarity coefficients (*J*) comparisons for non-infested (NI), infested (IF), and bio-control treatment (BC) sites in the silver sage, needle and thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Jaccard's (*J*) coefficient measures the degree of species similarity between the sites (N vs. IF, N vs. BC, and IF vs. BC). Jaccard's baseline coefficients (BL) reflect the amount of similarity between species among replicates within sites (n = 6 for all sites except green ash draw infested sites where n = 4) across the sites.42

Figure 3.4. Species present in extant vegetation, the corresponding seed bank and the number of species shared in non-infested (NI), infested (IF), and bio-control treated sites (BC) in the silver sage, needle and thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Species with frequencies of 17% or less were removed from comparisons. Jaccard's similarity index (*J*) indicates the level of similarity between the above ground and the seed bank species. Jaccard's baseline coefficients (BL) reflect the amount of similarity between species among replicates within sites (n = 6 for all sites except green ash draw infested sites where n = 4) across the sites.44

CHAPTER 1: INTRODUCTION

Loss of native plant productivity and bio-diversity resulting from plant invasions is a difficult, complex, and expensive issue facing public and private land managers. Invasive plants threaten many croplands, rangelands, aquatic areas and forests throughout the United States (Mullin 2000). Land management agencies have identified invasive species as a significant threat to federal lands and have recently developed policies and guidelines to address their control (Executive Order 13112 1999). Invasive species are defined in this executive order as: 1) non-native to the ecosystem under consideration, and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health.

Invasive plant species threaten the integrity of many natural systems throughout the world by displacing native plant communities (Kennedy et al. 2002). Many factors such as the physiological and morphological characteristics of the invasive plant, and the susceptibility of a plant community to invasion, influence the success of invading plant species. Numerous studies have focused on individual plant species and their specific attributes in relation to their ability to invade areas (Vitousek & Walker 1989; Thompson 1991; McClaran & Anable 1992; Edwards et al. 1995). Many studies have focused on understanding the life history characteristics and physiological traits of invasive plant species (e.g., Mooney et al. 1986; Orians 1986; Simberloff 1986; Crawley 1987; Lodge 1993). Physiologically, successful invaders are often characterized by high net primary

production, phenotypic plasticity, rapid growth rates, high fecundity, long-range seed dispersal and resistance to pathogens and pests (Bazzaz 1986). The leading hypothesis for the exceptional success of invasive plants is their escape from the natural enemies that serve as population control mechanisms allowing the invaders to utilize their full potential for resource competition (Keane & Crawley 2002). Disturbance is thought to also be important in opening communities to invasion due to the creation of altered habitats for invasive species establishment (Baker 1986; Hobbs 1989; D'Antonio 1993; Roberston et al. 1994; Medley 1997). Therefore, early to mid-successional communities may be more susceptible to invasion than late-successional communities (Rejmánek 1989). However, recent invasions have been documented in diverse native communities, high in herbaceous foliar cover and soil fertility (Stohlgren et al. 1999), posing a significant challenge to land managers and conservation biologists. Recovery and restoration techniques may be required to restore native plant community functional and structural characteristics following control of invasive species.

Leafy spurge (*Euphorbia esula* L., Euphorbiaceae) is a serious invasive rangeland species present throughout much of the Northern Great Plains (Selleck et al. 1962; Lajeunesse et al. 1999; Masters & Sheley 2001). This noxious weed currently infests approximately 1.5 million ha in 17 western states (North Dakota south to Texas and west to the Pacific coast) (Duncan & Clark 2005). Three prairie provinces of Canada are also infested with the Manitoba province described as the most severely affected (Rural Development Institute 2006). Current regional estimates of the economic impact of leafy spurge are unknown (Duncan et al. 2004), however, estimates of economic impacts of leafy spurge, including costs of control and loss of forage production, exceeded \$125

million annually in the Northern Great Plains (Montana, Wyoming, North Dakota and South Dakota) in the early 1990's (Leitch et al. 1994). Leafy spurge infestation decreases livestock carrying capacity (Lym & Kirby 1989), degrades native ungulate habitat (Trammell & Butler 1995) and effects native ecosystem functions such as nutrient cycling, fire frequency and forage production (Hein & Miller 1992). Leafy spurge infestations also decrease plant diversity by competing with native plant species (Belcher & Wilson 1989), including some of North Dakota's rare species (Anderson et al. 2000).

Leafy spurge is an aggressive long-lived deep rooted perennial plant introduced to North America in 1829 (Noble et al. 1979). Possible modes of introduction into North America include: (1) seed stock of Mennonite immigrants, (2) cereal seeds, (3) ship ballasts, or (4) bromegrass seed (Dunn 1985). Leafy spurge reproduces by seed and vegetatively by buds that occur on horizontal and vertical roots often forming dense monoculture stands of this species (Selleck et al. 1962). Plants can easily be identified from a distance by the pale green or blue green stem and showy yellow bracts. Inflorescences often appear in early to late May and continue through midsummer (Selleck et al. 1962). Seed is produced in a lobed capsule 20-30 days after flowering. A flowering stem has been reported to produce 250 or more seeds during a growing season (Bakke 1936). Seed dispersal is through dehiscence (hurtling seeds up to 4.5 m) (Hansen & Rudd 1933) from the lobed capsule and can be transported by animals via hooves, hair, and manure; by vehicles, and along waterways (Dunn 1985).

Efforts to control the spread of leafy spurge in the Northern Great Plains include the use of herbicides, burning, preferential grazing by lambs, and bio-control agents used singly and in combination as part of an integrated pest management strategy (Walker et

al. 1992; Gassmann & Schroeder 1995). Leafy spurge is a good candidate for biological control because it occurs at low densities in its native European habitat and appears to remain controlled (Wendel et al. 1992). Bio-control methods for leafy spurge, first initiated in the mid-1960's (Anderson et al. 2000), are thought to provide the best treatment for large leafy spurge infestation because of economic efficiency and restriction on herbicide use in ecologically sensitive areas (Spenser 1994; Bangsund 1996). Several species of insects introduced for biological control have proven effective, however, control in the Northern Great Plains has been achieved primarily by the *Aphthona* flea beetle species (*Aphthona nigricutis*, *A. czwalinae*, and *A. lacertosa* (Anderson et al. 2000). For a complete discussion of achievement and measurement of a 'successful' control program for leafy spurge, see Anderson et al. (2000). Studies have indicated that flea beetles can reduce leafy spurge stem densities by as much as 80-90% over large areas of the landscape (Anderson et al. 2000). Circular patches or 'halos' of dead leafy spurge stems are often observed in bio-control release areas around the area of initial release (Kalischuck 2004). These 'halo' areas once occupied by monoculture stands of leafy spurge are often barren of vegetation and present areas available for the re-establishment of species displaced by the initial infestation or new species through the seed bank. Insight into the differences between extant, resident vegetation and the soil seed bank, both in terms of composition and abundance, will be essential to develop management plans for full vegetation recovery following leafy spurge control.

Soil Seed Banks

The term 'seed bank' is conventionally used to characterize the reserves of viable seeds that are present in the soil and on its surface. Accumulations of seed in the soil provide plants with reserves and mechanisms to survive disturbance and allow for vegetation regeneration at a later date. Seed banks ensure the natural regeneration of a species if habitat disturbance or destruction caused by fire, heavy grazing, drought, flooding, or other events result in the death of plants (Grime 1981; Roberts & Neilson 1981; Baskin & Baskin 1998). Plant community seed banks represent the "memory" of previous conditions (Templeton & Levin 1979) and are an important component for the community to utilize in response to conditions in the present and future (Coffin & Lauenroth 1989).

In-situ seed banks are differentiated into two fundamental types, transient and persistent (Thompson & Grime 1979). Transient seed banks typically represent annual species that are adapted to exploit gaps that are created by seasonally predictable disturbances or mortality of plants. Transient seed banks do not persist in the soil, are generally found on the soil surface or in surface litter, and vary seasonally based on environmental conditions. Species that are prone to localized extinction have transient seed banks that are rapidly exhausted if seed input is reduced (Baker 1986). Persistent seed banks allow for regeneration in situations where disturbance or ecologically significant events are temporally or spatially unpredictable (Thompson & Grime 1979). Species present in persistent seed banks are commonly found in soil and often respond to environmental cues for establishment. The ability of seeds to remain viable in soil for extended periods of time and to contribute to regeneration at later dates is often referred

to as seed dormancy or the dormant seed bank fraction of the persistent seed bank (Thompson & Grime 1979).

Seed banks represent a vast pool of potential regenerative material to restore or re-vegetate lands impacted by invasive species. The recovery of individual species from seed banks is considered one of the most relevant factors contributing to the maintenance and preservation of impacted communities (Fenner 1985). Seed banks profoundly affect the composition and future vegetation patterns within a community (Egler 1954; Harper 1977). Seed bank analyses indicate they are strong predictors of future plant cover in semi-arid plant communities (Olano et al. 2005) and cultivated agronomic fields with respect to weed re-establishment (Wilson et al. 1985). Additionally, seed banks in native prairie wetlands have also been shown to be a major source for establishment of plant species that propagate by seed (van der Valk & Davie 1978; Welling et al. 1988). In contrast, seed bank studies of disturbed drained marshes have been shown to be poor predictors of future vegetation following re-establishment of wetland hydrology in Lake Ontario and St. Lawrence River plains in New York (Brown 1998). Recruitment potential from seed banks in grasslands and forests is generally only expressed in a narrow subset of microsites (Ericksson & Ehrlén 1992; Davies & Waite 1998; Moles & Drake 1999). Although a number of seed bank investigations have been conducted in natural grassland communities (Rabinowitz & Rapp 1980; Rabinowitz 1981; Perez et al. 1998), none have addressed the impacts of invasive species and biological control on the relationship of above ground vegetation with seed banks.

Scope of this Study

I conducted this research within the South Unit of Theodore Roosevelt National Park (TRNP), North Dakota, because of recent vegetation mapping, current leafy spurge research, and the implementation of an aggressive bio-control program. The vegetation mapping provided information on hierarchical classification and general composition distribution of plant communities in the Park. Geographical information systems data available from TRNP databases provided bio-control treatment locations.

Vegetation mapping of TRNP began in May, 1997 and was completed in 2000 and provided baseline inventories of the biological and geophysical resources of the Park. Vegetation map classes were determined through extensive field reconnaissance and data collection and analysis in accordance with the National Vegetation Classification System (Grossman et al. 1998). Mapping results for TRNP identified 27 natural and semi-natural associations comprised of 8 woodland, 8 shrubland, 5 upland herbaceous/grassland, 2 wetland and 4 sparse vegetation types (Von Loh et al. 2000). The overall accuracy for the entire mapping effort was assessed at 74% (Von Loh et al. 2000) (maps available online at <http://biology.usgs.gov/npsveg/thro>).

A considerable amount of research on invasive plants and bio-control has been conducted within TRNP. Everitt et al. (1995) used remote sensing and aerial photography to detect and map leafy spurge. Trammell & Butler (1995) evaluated the effects of exotic plants on native ungulate use of habitat. Brinkman et al. (1996) evaluated the reproductive status of *Aphthona* flea beetles. Irby et al. (2002) developed forage allocation models in response to leafy spurge infestation. Butler (1994) evaluated effects of herbicide treatments on leafy spurge and non-target species. Lenz (1994)

assessed leafy spurge impacts on rare plants. Butler & Cogan (2004) researched leafy spurge effects on plant species richness. Larson & Grace (2004) investigated temporal dynamics of leafy spurge and flea beetles. Larson et al. (2001) and studied the effects of vegetation type and anthropogenic disturbances in the mixed grass prairie, and native weeds and exotic plants in relation to disturbance (Larson 2003).

More than 1,800 releases and redistributions of bio-control flea beetles (*Aphthona* spp.), averaging more than 2000 insects per release, were made in leafy spurge infested areas of the Park between 1989 and 1997 (TRNP database records). Each release point was recorded using a global positioning system receiver and entered into a geographic information system database. Specific levels of leafy spurge infestation were not recorded for these individual points. In 1993, based on aerial photos, TRNP reported that approximately 3% of the South Unit of the Park was infested with leafy spurge (Anderson et al. 1996). A more current estimate of leafy spurge infestation within the South Unit of the Park is reported to be 10% (USDI-NPS, 2005).

Leafy spurge infested, leafy spurge infested with bio-control treatment, and non-infested sites in three vegetation associations were chosen for the study. Silver Sagebrush/Western Wheatgrass Shrubland Association, Green Ash-American Elm/Choke Cherry Woodland Association, and Needle-and-Thread-Blue Grama-Thread Leaf Sedge Herbaceous Associations are thought to be most impacted by leafy spurge infestation (P. Andersen, pers. comm. 2000; J. Butler, pers. comm. 2000) and these associations may reflect the chronological sequence of leafy spurge infestation within the Park. The chronological sequence of leafy spurge invasion into the Park may have initially occurred within the mesic and disturbed floodplains, spreading into the upland drainages and

draws, and finally up to the upland grasslands and shrublands (Anderson et al. 1996). Based on the ability of seed banks to provide a source of seed for future establishment in impacted areas, the relatively recent invasion of leafy spurge in the Park, and previous mapping indicating considerable redundancy in species distribution among a wide variety of plant associations, my prediction is that bio-control sites will recover to similar patterns to those observed in non-infested sites.

Objectives and Hypotheses

The objectives of my study were to evaluate native species vegetation recovery in areas previously infested with leafy spurge and treated with the bio-control agent *Aphthona* spp. and to examine the in-situ seed bank to predict future recovery of native species previously impacted by leafy spurge invasion. It was hypothesized that extant species richness, diversity, composition, frequency of occurrence and community assemblages in the bio-control sites would be more similar to those found in non-infested sites compared to infested sites. It was also hypothesized that seed banks in bio-control treated areas would more closely resemble seed banks in non-infested areas in species richness, composition, frequency of occurrence and community assemblages, and that leafy spurge seed density would be reduced indicating recovery. Finally, it was hypothesized that seed bank comparisons with extant vegetation could provide a method to predict potential future communities in these impacted areas and that seed banks in one site may predict vegetation in other sites.

CHAPTER 2: STUDY AREA AND METHODS

Study Area

The study area is located in the 18,600 ha. South Unit of TRNP (46° 55'N, 103° 31' W) in southwestern North Dakota (Figure 2.1). Over 404,600 hectares of the Little Missouri National Grasslands and the Custer National Forest surround the Park. Surface geology is semiarid rolling plain comprised of shale, siltstone and sandstone punctuated by occasional buttes and badlands (Von Loh et al. 2000). The climate is semi-arid and continental in nature that includes short, hot summers and long, cold winters. Most precipitation events occur in late spring and early summer. Predominant soil orders include entisols and mollisols (Wali et al. 1980).

The complex topography of the area supports a variety of wildlife and vegetation. Important herbivores include white-tailed deer (*Odocoileus virginianus*) commonly associated with tree-covered drainages; mule deer (*Odocoileus hemionus*) found in brush covered draws and open uplands; bison (*Bison bison*) and wild horses (*Equus spp.*) that utilize a variety of open habitats; and elk (*Cervus elaphus*) that feed in open grasslands and utilize woodlands for cover (USDI-NPS 2005). Silver Sagebrush/Western Wheatgrass Shrubland Association (hereafter referred to as silver sage vegetation association), Green Ash-American Elm/Choke Cherry Woodland Association (hereafter referred to as green ash draw vegetation association), and Needle-and-Thread-Blue Grama-Thread Leaf Sedge Herbaceous Association (hereafter referred to as needle-and-

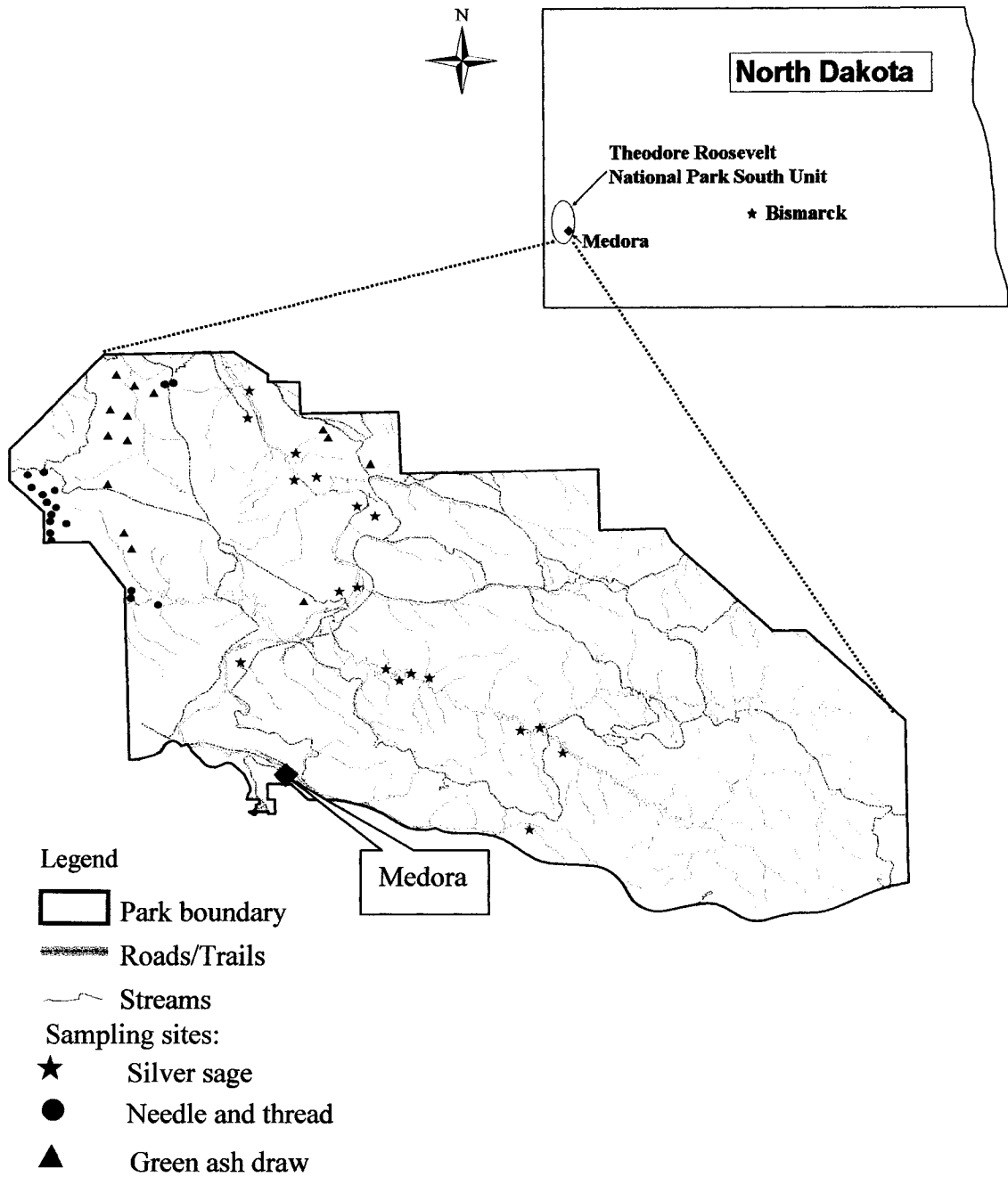


Figure 2.1. Location map showing park boundary, roads, trails, streams and sampling sites located in silver sage, needle-and-thread, and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND.

thread vegetation association) as described in the recent mapping (Von Loh et al. 2000) are the most impacted by leafy spurge infestation (P. Andersen, pers. comm. 2000; J. Butler, pers. comm. 2000). Leafy spurge had infested up to 702 ha (3%) of the land base of the southern unit of TRNP in 1993 (Anderson et al. 1996). About 1,600 ha (10%) of the South Unit were infested in 2005 (USDI-NPS 2005). Anderson et al. (1996) suggested the sequence of leafy spurge invasion into TRNP initially started in the more mesic disturbed floodplain areas and spread into the upland areas via draws and drainages. In this context, more mature stands of leafy spurge are assumed to occur in the silver sage vegetation association, followed by the green ash, and needle-and-thread associations. The first bio-control agents were released into TRNP in 1989 (a small research test plot). An aggressive leafy spurge treatment with herbicides and bio-control agents (*Apthona* spp.) has been implemented in TRNP for the past 12 years (USDI-NPS 2005; L. Richardson pers comm. 2005).

Silver sage vegetation association

The silver sage vegetation association (approximately 3% of the park) is common along stream bottoms and first and second terraces of the Little Missouri River and its major tributaries (Von Loh et al. 2000). Silver sage vegetation associations form the prominent and relatively large “sagebrush flats” that occur on nearly flat and gently sloping floodplains. Silver sagebrush (*Artemisia cana*) is the dominant shrub species while western wheatgrass (*Pascopyrum smithii*) is the major herbaceous species. Other abundant species include green ash, (*Fraxinus pennsylvanica*) snowberry (*Symphoricarpos occidentalis*), smooth brome (*Bromus inermis*) and leafy spurge. The

silver sage vegetation association is important habitat for many nesting birds (Walcheck 1970; Rowland 2004; Walker 2004)

Needle-and-thread vegetation association

The needle-and-thread vegetation association is common in the upland areas of the Park and is considered to be the most extensive herbaceous vegetation association in TRNP and the land surrounding the Park (~38 and ~44% respectively) (Von Loh et al. 2000). This grassland association occupies plains, flats on buttes, plateaus, mesa tops and hillsides and is considered to be the climax community for the region. It is manifested by a matrix of large patches that are frequently found dominating whole landscapes (Von Loh et al. 2000). Common herbaceous species include needle-and-thread (*Heterostipa comata*), blue grama (*Bouteloua gracilis*) and threadleaf sedge (*Carex filifolia*). These grasslands are often grazed by bison, deer and pronghorn (*Antilocarpa americana*) (USDI-NPS 2005).

Green ash draw vegetation association

The green ash draw vegetation association occurs in various ephemeral locations throughout the Park and represents unique vegetative communities. About 767 ha representing approximately 4% of the Park have been mapped (Von Loh et al. 2000). Green ash draws occur in upland ravines and within broad valleys or on moderately steep slopes in narrow bands. Common tree species, in addition to green ash, consist of American elm (*Ulmus americana*) and box elder (*Acer negundo*). Choke cherry (*Prunus virginiana*), snowberry, and western wild rose (*Rosa woodsii*) are common short shrubs while Kentucky bluegrass (*Poa pratensis*), longbeak sedge (*Carex sprengei*) and northern bedstraw (*Galium boreale*) are common herbaceous species (Von Loh et al.

2000). Green ash draws are considered to be important habitat for a number of wildlife species and provide important year-round browse and shelter habitat for both mule and whitetail deer (Girard et al. 1987). Upland draw areas in the green ash draw association constitute up to 50% of the critical habitat for deer throughout much of the Great Plains (Bjugstad & Uresk 1983). Other mammal species commonly found in upland draw areas include squirrels (*Tamiasciurus* spp.), coyotes (*Canis latrans*), rabbits (*Sylvilagus* spp.), raccoons (*Procyon lotor*) and porcupines (*Erethizon dorsatum*). The green ash draw vegetation association is essential for the breeding, nesting and fledging of a number of avian species (Faanes 1984; Girard et al. 1987; Rumble & Gobeille 1998). A rich diversity of invertebrate species are also present in these woodland habitats (Girard 1985).

Field Methods

I selected non-infested leafy spurge sites (here after referred to as non-infested and noted in tables and figures as NI), leafy spurge infested sites (hereafter referred to as infested and noted in tables and figures as IF), and sites previously infested with leafy spurge and treated with bio-control (hereafter referred to as bio-control and noted in tables and figures as BC) in each of the three vegetation associations. Six replicates per site for each vegetation association were located throughout the Park except in green ash draw infested sites where $n = 4$. The design for each vegetation association is shown in

Table 2.1.

Table 2.1 Treatment design within three vegetation associations in the South Unit of Theodore Roosevelt National Park, ND.

Vegetation Association	Sites (replicates)			Total Sites
	NI	IF	BC	
Silver sage	6	6	6	18
Needle-and-thread	6	6	6	18
Green ash draw	6	4	6	16
Total				52

Non-infested sites were selected based on absence of leafy spurge plants. Infested sites were selected based on dominance of leafy spurge plants. I used TRNP records (GIS data) and field reconnaissance to select bio-control release sites and used the following criteria for site selection: 1) bio-control sites receiving one release of approximately 1,000 or more *Aphthona lacertosa* individuals in either 1995, 1996 or 1997, 2) field verification of infestation as indicated by dead leafy spurge canes or in some instances halos, 3) field verification of flea beetle activity, and 4) proximity away from other bio-control release sites (at least 80 m). Because of inherent error associated with GIS data and the time period since release, these sites were actual best estimates of exact bio-control release locations. Infested and non-infested sites were also selected to closely match similar landscape characteristics, such as aspect, soil type and slope, found in bio-control release sites. Individual site locations are identified in Figure 2.1.

Vegetational Analyses

I conducted vegetational site analyses in late June 2002 on all 52 sites using a modification of the Modified Whitaker field plot technique (Figure 2.2) (Stohlgren et al.1998). Plot modifications included the elimination of the two 5 x 2 m² subplots within the 1000 m² plots. Foliar cover estimates of each species were placed into 1 of 6 cover

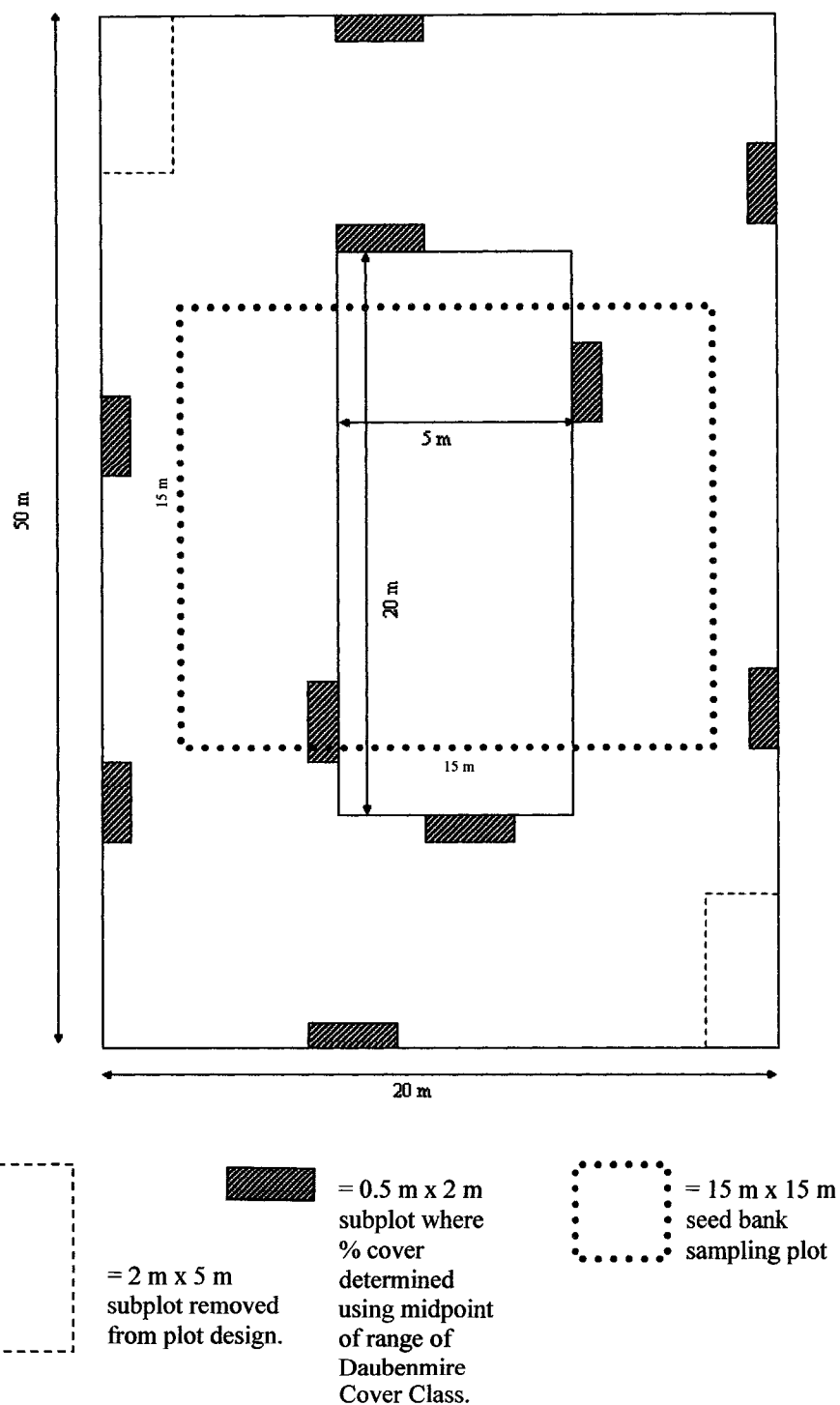


Figure 2.2. Modification of the Modified Whitaker plot design and seed bank sampling plot area used in this study. Extant species occurrences were recorded (June, 2002) within 1000 m² and 100 m² area and percentage cover by species was recorded for each 0.5 m x 2 m area using Daubenmire cover class determinations (Daubenmire, 1959). Thirty randomly selected seed bank samples (based on a 225 m² grid) consisting of surface material and soil cores (10 cm diameter by 5 cm deep) were collected Sept. 2001 and June 2002.

classes (Daubenmire, 1959) instead of actual percent cover estimates and the mid-points of the classes were used to calculate mean foliar cover. The six foliar cover classes were: 1 = 0-5%, 2 = 6-25%, 3 = 26-50%, 4 = 51-75%, 5 = 76-95%, and 95-100%. Plant nomenclature followed Barkley (1986) and Johnson and Larson (1999). Non-native species defined in this study follow Northern Great Plains Floristic Quality Assessment Panel recommendations (2001).

Seed Bank Sampling

Seed bank samples were collected within a 15 x 15 m area located in the center of each Modified Whitaker plot selected for the vegetation analysis (Figure 2.2). I used a random number generator to identify 30 subplots for sampling within the 15 x 15 m site (x, y coordinates). Surface litter and soil cores were collected from each of the 30 subplots using a 10 cm diameter by 5 cm deep circular golf cup cutter and mixed together. I separated the seed bank into three fractions: persistent, dormant, and transient. Surface litter samples represented the transient seed bank fraction while the soil cores represented the persistent and dormant seed bank fractions. I sampled the persistent and dormant seed banks (soil cores) and the late transient seed bank in September 2001, and the early transient seed banks in June 2002 (Table 2.2). I was unable to identify the previous seasons' random soil core sites (September, 2001), therefore, I selected 30 new random sites within each plot to collect the early transient seed bank samples in 2002.

Table 2.2. Seed bank fractions, sampling dates and field sampling design by vegetation association.

Seed bank fraction	Sample date	Number of replicates per site (1 replicate = 30 subsamples/site)									Total
		Silver sage			Needle-and-thread			Green ash draw			
		NI	IF	BC	NI	IF	BC	NI	IF	BC	
Persistent	9/2001	6	6	6	6	6	6	6	6	4	52
Dormant*	9/2001	6	6	6	6	6	6	6	6	4	52
Transient – late	9/2001	6	6	6	6	6	6	6	6	4	52
Transient – early	6/2002	6	6	6	6	6	6	6	6	4	52

* Dormant fraction is a subset of the persistent seed bank.

Seed Bank Identification

I placed all soil and late transient seed bank samples in controlled conditioning rooms equilibrated at 5°C and 25% relative humidity for approximately 130 days to meet any necessary seed prechilling requirements. Persistent seed bank samples (soil cores) were sieved through a 1.5 cm screen to remove large twigs and root masses and through a 0.3 mm screen to remove fine soil material, while retaining the smallest seed size expected to be found within samples. The remaining soil (persistent and dormant seed bank fractions) was then placed in seed flats lined with filter cloth and approximately 2 cm sterile sand. The flats were placed in a greenhouse in a completely randomized design and watered from above on a regular basis. The surface litter from late and early transient seed bank samples was placed on the surface of a sterile germination soil mix and placed in the greenhouse in a completely randomized design. The late transient seed fraction collected September of 2001 received a cold stratification treatment (5°C and 25% relative humidity for approximately 130 days), whereas the seed bank fraction collected in the early summer of 2002 did not receive cold-stratification treatment prior to germination tests in the greenhouse. Greenhouse conditions were controlled to germinate seeds by maintaining temperatures between 10°C and 30°C and supplemented with additional lighting to maintain 16 h of light.

Individual seedlings were identified as they emerged and grouped into forbs, graminoids, trees, shrubs, and vines, and sub-groups of non-native forbs, non-native grass, annuals, biennials, and perennials, following the nomenclature, growth form, and functional types found in Barkley (1986), Johnson and Larson 1999, and the Northern Great Plains Floristic Quality Assessment Panel (2001) studies. If plants could not be identified after 148 days (approximately 5 months), they were transferred to pots and grown until positive identification could be made at a later date.

At the end of the greenhouse germination trials, the remaining soil from each site (green house persistent emergence study) was elutriated and blown to further separate the seed fraction from bulk soil samples so that the remaining seeds in soil cores representing the dormant fraction of the persistent seed bank could be identified. The elutriation process used pressurized water to force remaining soil through a 0.318 mm screen. The remaining sample, containing all particles including seed and soil particles larger than 0.318 mm, were quickly dried to prevent any potential seed imbibition that could affect viability tests. This protocol was developed by USDA-ARS Water Management Research Unit, Fort Collins, CO and has been very successful in reducing the soil fraction, retaining all seed, and maintaining seed viability (Wiles et al. 1996). Additional sample blowing was conducted using a General Seed Blower (New Brunswick Sheet Metal Works) to further reduce the sample size required for microscopic identification. Samples retained from the elutriation process and additional blowing were then microscopically examined and seeds were identified using descriptions and keys from USDA Forest Service (1985), USDA Soil Conservation Service (1968), and Davis (1993) as well as expert advice from various seed analysts at USDA Agricultural Research

Service National Center for Genetic Resources (Fort Collins, CO), USDA Agricultural Research Service Water Resources Division (Fort Collins, CO), and Colorado State Seed Laboratory (Fort Collins, CO). After positive identification, seeds were tested for viability using the tetrazolium method (AOSA 2002). If methods were not published for a particular species, methods listed for similar species or genera were followed.

Statistical Analyses

Extant vegetation

I compiled species occurrences and cover for all sites (non-infested, infested and bio-control) within a vegetation association. All species occurrence and cover data were tested for normality using Shapiro-Wilk test (SAS 2002). I calculated Shannon Weiner diversity indices (H') (Zar 1999) to evaluate the effect of leafy spurge infestation and bio-control on species diversity and to take into account both the number of species and the relative cover of each species. The Shannon Weiner index was computed as follows:

$$H' = \sum_{i=1}^S p_i \times \ln p_i ,$$

where:

H' = the Shannon-Wiener diversity index,

S = the number of species in the sample, and

p_i = the relative cover of the i^{th} taxa in the sample.

Because the data did not meet the assumption of normality, I used the Kruskal-Wallis rank test (Hollander and Wolf, 1999; USDA Forest Service, Rocky Mountain Research Station 2004) to evaluate treatment effects on species richness, H' , and by individual vegetation growth forms and non-native species composition.

I calculated species frequencies based on occurrence within sites (1000m² plot) for each vegetation association to evaluate and summarize the: 1) impacts to individual

species in the infested and bio-control treatment plots, 2) common and persistent species not impacted by treatments, 3) weedy species fluctuations in response to treatment, and 4) species that increased within infested and bio-control sites. I defined common, persistent, occasional and increaser species for the purposes of this study as follows: common species are species with frequencies equal to or greater than 67% within a site, persistent species are species with frequencies equal to or greater than 67% in non-infested and infested plots and are assumed to be minimally impacted by leafy spurge, occasional species are species with frequencies between 34% and 50% within a site, and increaser species are species shown to increase in frequency (50% or more) or average cover (10% or more) in bio-control sites compared to non-infested sites.

I used a multivariate statistical model developed by Dyer (1978) to evaluate the impacts of leafy spurge within each site using the Jaccard's similarity coefficient (J) for species presence and the Bray-Curtis dissimilarity index (D_{ij}) for species foliar cover and weedy species cover as determined by the Northern Great Plains Quality Assessment Panel (2001). Jaccard's coefficient measures the compositional overlap between two complete species lists as follows: $J = A/(A+B+C)$, where A = the number of species found in both paired sites, B = species in site 1 but not in site 2, and C = species in site 2 but not in site 1. A comparison of species assemblages between two sites that produce a similarity coefficient (J) of 1.0 would indicate complete overlap species composition, whereas a coefficient of 0 would indicate no compositional overlap. Bray Curtis dissimilarity coefficient (D_{ij}) is more sensitive to abundance data of individual species and was calculated as follows:

$$D_{ij} = \frac{\sum_{k=1}^K w_k |X_{ik} - X_{jk}|}{\sum_{k=1}^K w_k (X_{ik} + X_{jk})} = 1 - \frac{2 \sum_{k=1}^K w_k \min(X_{ik}, X_{jk})}{\sum_{k=1}^K w_k (X_{ik} + X_{jk})},$$

where X_{ik} and X_{jk} are the k -th characters for the i_{th} and j_{th} observations and w_k their weight. Weight (w_k) in these analyses equals 1. Bray-Curtis dissimilarity coefficients indicate the degree of dissimilarity between communities where a value of 1 = no overlap in composition or abundance between communities and a value of 0 = complete overlap of species composition and abundance within the two comparing communities. For both J and D_{ij} coefficients, baseline values that represent the mean variability among replicates between the two communities being compared are also presented as a reference point.

Seed bank

A completely randomized design was used for green house emergence studies. I tested all data for normality using Shapiro-Wilks test (SAS 2002). Because non-normality was prevalent, I used the Kruskal-Wallis test at $\alpha = 0.05$ (Hollander & Wolfe 1999; USDA-Forest Service 2004) to evaluate species richness differences among the sites in each vegetation association for each seed bank fraction. Species were also summed across seed bank fractions to represent the seed bank as a whole (total seed bank) and differences in species richness, species composition, leafy spurge seed density, and non-native forbs and non-native grass seed density differences between non-infested, infested, and bio-control sites for each vegetation association were tested using the Kruskal-Wallis test.. Frequencies for each species were calculated across the replicates within each site based on number of occurrences among sites within a vegetation association. For example, a species frequency of 50% in the dormant fraction of a silver sage infested site indicates that the species occurs in three of the six replicates. Additionally, for the total seed bank calculations, where the transients, persistent and

dormant seed bank fractions were summed for each replicate, a frequency of 50% in the total seed bank of a silver sage infested site indicates that a species occurs in three of the six replicates. Because seed banks vary spatially and temporally, a frequency of 50% or more was chosen to represent common species within the seed bank fraction.

I used a multivariate statistical model developed by Dyer (1978) using Jaccard's similarity coefficient (J) to evaluate seed bank composition and each species potential contribution, based on presence of seed, to future trends in extant vegetation. I tested the following combinations of seed banks and seed bank by extant vegetation within each vegetation association:

1. similarity of total seed bank species between sites,
2. similarity between extant vegetation species and total seed bank species within and among sites,
3. similarity between extant vegetation species and total seed bank species between sites, and
4. similarity between commonly occurring extant species and total seed bank species between sites.

Additionally, individual unique species occurrences were totaled across all replicates within a site and were compared to unique species occurrences across all replicates within the site for each vegetation association. These percentage comparisons of species occurrences between the extant vegetation and seed bank occurrences provide an overall comparison for a broader scale interpretation vs. the J and D_{ij} similarity and dissimilarity coefficients that provide a site by site comparison.

CHAPTER 3: RESULTS

Resident Vegetation Analyses

Species Richness and Composition

The total number of species identified in the silver sage, needle and thread, and green ash draw vegetation associations was 143, 145, and 157, respectively (see extant species list in Appendix A, Table 1). Mean species richness and diversity were similar ($p \geq 0.05$) among sites across all vegetation associations (Table 3.1). Comparatively, the green ash draw vegetation association was more species rich and had higher diversity indices (H') than the silver sage and needle and thread vegetation associations. Larger plot sizes (1000 m²) within the Modified Whitaker plot design accounted for an increase in species richness of 37-46% above 100 m² plot values.

Forbs were reduced 13 to 32% in bio-control sites ($p \geq 0.05$) compared to non-infested sites, and 0 to 34% in infested sites across all three vegetation associations (Table 3.2). Graminoids, shrubs, and tree richness were similar across all sites within a vegetation association. No differences were observed between mean richness of non-native forbs and non-native grass. However, non-native species comprised a higher percent of the total number of species in the infested and bio-control sites compared to non-infested sites (Table 3.2). No individual non-native forb or grass species was associated with any site or vegetation associations. No significant differences were detected between average cover among sites for each vegetation association (with leafy

Table 3.1. Mean species richness and standard deviations \pm , of the 100 m² and 1000 m² plots within the modification of the Modified Whitaker sampling method and Shannon Wiener diversity indices (H') for non-infested (NI), infested (IF), and bio-control (BC) sites in silver sage, needle-and-thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Data were collected June, 2002.

Site	Silver sage			Needle-and-thread			Green ash draw		
	Mean Richness*		Diversity*	Mean Richness		Diversity	Mean Richness		Diversity
	100 m ²	1000 m ²	H'	100 m ²	1000 m ²	H'	100 m ²	1000 m ²	H'
NI	23a \pm 9.9	38a \pm 12.6	2.2a \pm 0.29	23a \pm 4.2	44a \pm 5.4	2.4a \pm 0.41	25a \pm 18.2	48a \pm 10.6	2.5a \pm 0.33
IF	21a \pm 7.7	30a \pm 5.5	2.1a \pm 0.20	26a \pm 3.1	45a \pm 9.7	2.2a \pm 0.57	31a \pm 0.2	47a \pm 5.7	2.7a \pm 0.39
BC	18a \pm 4.0	30a \pm 7.0	2.0a \pm 0.20	21a \pm 6.1	40a \pm 8.4	2.2a \pm 0.34	31a \pm 6.1	43a \pm 6.7	2.5a \pm 0.52

* Letters in common (within a column) designate no significant differences detected between treatments at $p \geq 0.05$ using Kruskal-Wallis test

Table 3.2. Mean species richness by growth form and vegetation association, standard deviations \pm , and total number of species (in parentheses) in non-infested (NI), infested (IF) and bio-control (BC) 1000m² sites in three vegetation associations located in the South Unit of Theodore Roosevelt National Park, ND. Non-native species determined by North Dakota state coefficients of conservation (Northern Great Plains Floristic Quality Assessment Panel 2001).

Growth form	Silver sage ¹			Needle-and-thread ¹			Green ash draw ¹		
	NI	IF	BC	NI	IF	BC	NI	IF	BC
Forbs	25a \pm 7.8 (66)	16a \pm 4.4 (34)	17a \pm 5.0 (39)	31a \pm 5.2 (72)	31a \pm 5.0 (64)	27a \pm 5.3 (65)	31a \pm 7.7 (68)	29a \pm 5.7 (57)	27a \pm 4.9 (61)
Graminoids	9a \pm 7.8 (16)	9a \pm 2.3 (17)	9a \pm 2.7 (18)	10a \pm 2.3 (15)	10a \pm 1.5 (15)	9a \pm 2.1 (17)	8a \pm 2.7 (16)	9a \pm 0.8 (16)	6a \pm 1.6 (12)
Shrubs	4a \pm 3.1 (10)	4a \pm 0.8 (8)	4a \pm 1.4 (5)	3a \pm 2.6 (8)	3a \pm 1.2 (8)	4a \pm 2.8 (9)	7a \pm 1.2 (12)	7a \pm 0.5 (9)	8a \pm 1.1 (12)
Trees	0 \pm 1.8 (1)	0 \pm 0.8 (2)	1 \pm 0.9 (2)	0 \pm 0.0 (0)	0 \pm 0.0 (0)	0 \pm 0.4 (1)	2a \pm 0.9 (3)	2a \pm 0.8 (4)	3a \pm 0.6 (3)
Non-native forbs	6a \pm 1.4 (9)	6a \pm 2.3 (9)	5a \pm 1.9 (9)	5a \pm 1.4 (8)	5a \pm 2.3 (9)	4a \pm 2.3 (7)	4a \pm 1.7 (8)	6a \pm 1.3 (12)	5a \pm 0.8 (10)
Non-native grass	3a \pm 0.9 (4)	3a \pm 0.6 (6)	2a \pm 1.7 (4)	1a \pm 0.9 (2)	1a \pm 0.8 (3)	1a \pm 1.0 (4)	2a \pm 0.0 (3)	3a \pm 1.9 (4)	2a \pm 0.6 (2)
Total species	(106)	(76)	(77)	(105)	(99)	(103)	(110)	(102)	(100)
Percent non-native species ²	12%	20%	17%	10%	12%	11%	10%	16%	12%

¹ Letters in common within a row by vegetation type denote no significant difference detected at $p \leq 0.05$ using Kruskal-Wallis test.

² Percent non-native species calculated by number non-native species (forbs and grasses) divided by total number of species.

spurge component removed from data set) using dissimilarity analyses (D_{ij}) (data not shown).

Non-native grass species most commonly identified in all three vegetation associations were: smooth brome (*Bromus inermis*), Japanese brome (*B. japonicus*), downy brome (*B. tectorum*), annual bluegrass (*Poa annua*), Canada bluegrass (*Poa compressa*), and Kentucky bluegrass (*P. pratensis*). Non-native forbs were: common burdock (*Arctium minus*), little pod false flax (*Camelina microcarpa*), lambs quarters (*Chenopodium album*), Canada thistle (*Cirsium arvense*), flixweed, (*Descurainia sophia*), leafy spurge, prickly lettuce (*Lactuca serriola*), yellow sweet clover (*Melilotus officinalis*), dandelion (*Taraxacum officinale*), and salsify (*Tragopogon dubius*).

Vegetation Association Trends

Forbs (including non-native forbs) and graminoids comprised 56 and 25% of the common and persistent species respectively, across the three vegetation associations (Table 3.3). Remaining shrubs and trees constituted 19% of the persistent species across the three vegetation associations. Western wheatgrass and green needlegrass (*Nasella viridula*) were common to all vegetation associations (Table 3.3). The silver sage vegetation association had two forbs, three non-native forbs, one non-native grass, two grass and two shrub species. The needle and thread vegetation association had nine forbs, five grasses and one sedge species. The green ash draw vegetation association had seven forbs, one non-native forb, one non-native grass, three grass, five shrubs, and one tree species.

Nineteen species were impacted by leafy spurge as shown by reduced frequencies in infested sites (Table 3.4) and are considered common/sensitive or

Table 3.3. Common and persistent extant vegetation species in silver sage (SS), needle-and-thread (NT) and green ash draw (GA) vegetation associations within the South Unit of Theodore Roosevelt National Park, ND. Persistent species are species with frequencies of 67% or more within non-infested, infested and bio-control sites (n = 6 for all sites except n = 4 for green ash draw infested sites). Vegetation analyses conducted June, 2002.

Species	Community	Form ¹
<i>Achillea millefolium</i>	SS,GA	F
<i>Artemesia cana</i>	SS, GA	S
<i>A. frigida</i>	NT	F
<i>A. ludoviciana</i>	GA	F
<i>Aster ericoides</i>	NT	F
<i>Bouteloua gracilis</i>	NT	F
<i>Carex filifolia</i>	NT	Sdg
<i>Elymus virginicus</i>	GA	G
<i>Euphorbia esula</i>	SS	f-w
<i>Fraxinus pennsylvanica</i>	GA	T
<i>Galium aparine</i>	GA	F
<i>G. boreale</i>	GA	F
<i>Gaura coccinea</i>	NT	F
<i>Helianthus spp.</i>	NT	F
<i>Hesperostipa comata</i>	NT	G
<i>Koeleria pyramidata</i>	NT	G
<i>Lactuca oblongifolia</i>	NT, GA	F
<i>Melilotus officinalis</i>	SS	f-w
<i>Opuntia spp.</i>	NT	F
<i>Nasella viridula</i>	SS, NT, GA	G
<i>Pascopyrum smithii</i>	SS, GA, NT	G
<i>Poa pratensis</i>	SS, GA	g-w
<i>Polygala alba</i>	NT	F
<i>Prunus virginiana</i>	GA	S
<i>Rhus aromatica</i>	GA	S
<i>Rosa spp.</i>	GA	S
<i>Schizachyrium scoparium</i>	NT	G
<i>Smilacina stellata</i>	GA	F
<i>Symphoricarpos occidentalis</i>	SS, GA	S
<i>Taraxacum officinale</i>	GA	f-w
<i>Thalictrum dasycarpum</i>	GA	f
<i>Tragopogon dubius</i>	SS, NT	f
Total	32	18 forbs, 8 grass/sedges. 5 shrubs, 1 tree

¹Form designations: f = forb, g = grass, s = shrub, sdg = sedge, t = tree, w = non-native species as defined by North Dakota Coefficients of Conservation (2001).

Table 3.4. Site frequencies of species affected by leafy spurge infestation in non-infested (NI), infested (IF), and bio-control (BC) sites in silver sage (SS), needle-and-thread (NT), and green ash draw (GA) vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Common/sensitive species occur at frequencies of 67% or more in non-infested sites, yet were reduced by 50% or more in infested sites. Occasional sensitive species were species that occur within the non-infested sites at frequencies of 34-50% yet were absent in infested sites. Frequencies were based on 1000 m² plots.

Species Common/sensitive	Vegetation association	NI	IF	BC
<i>Amaranthus albus</i> (f)	GA	67	0	50
<i>Artemisia ludoviciana</i> (f)	NT	67	0	50
<i>Dalea purpurea</i> (f)	NT	67	33	50
<i>Echinacea angustifolia</i> (f)	NT	83	33	67
<i>Euphorbia spathulata</i> (f)	SS	83	33	67
<i>Euphorbia spathulata</i> (f)	GA	67	25	17
<i>Linum lewisii</i> (f)	NT	83	33	50
<i>Poa pratensis</i> (wg)	NT	67	0	50
<i>Sphaeralcea coccinea</i> (f)	SS	67	0	17
<i>Symphoricarpos occidentalis</i> (s)	NT	83	33	67
Occasional/sensitive				
<i>Achillea millefolium</i> (f)	NT	50	0	50
<i>Allium textile</i> (f)	SS	33	0	17
<i>Collomia linearis</i> (f)	SS	50	0	17
<i>Galium aparine</i> (f)	SS	33	0	33
<i>Kraskinninikovia lanata</i> (s)	SS	33	0	0
<i>Lithospermum incisum</i> (f)	SS	33	0	33
<i>Opuntia</i> spp. (f)	SS	33	0	17
<i>Polygonium douglasii</i> (f)	SS	33	0	0
<i>Potentilla pensylvanica</i> (f)	SS	33	0	17
<i>Psoralea argophylla</i> (f)	SS	50	0	17

* f = forb, s = shrub, wg = non-native grass

occasional/sensitive species. Sixteen of these species were forbs. Common/sensitive species occur at frequencies of 67% or more in non-infested sites yet were reduced by 50% or more in infested sites. Occasional sensitive species are species that occur at frequencies of 34-50% in non-infested sites, yet were absent in the infested sites. Eleven of these sensitive species were located in the silver sage vegetation association. Seven sensitive species were identified in the needle and thread vegetation association and two sensitive species were identified in the green ash draw vegetation association. Nine of the 11 species affected in the silver sage vegetation association had frequencies between 17-67% in bio-control sites and in all instances had higher frequencies than those observed in infested sites (Table 3.4). Eighty nine percent of identified sensitive species (19 species) were documented in bio-control sites at a frequency of 17% or more and 47% (nine species) of sensitive species had frequencies of 50% or more (Table 3.4). Only two sensitive species, winterfat (*Krascheninnikovia lanata*) and knotweed (*Polygonium douglasii*), were totally absent in bio-control sites and one species, prairie spurge (*Euphorbia spathulata*), had a lower frequency in the bio-control sites than in the infested sites (Table 3.4).

Seventeen increaser species (5 forbs, 8 graminoids, 2 shrubs, and 1 tree) were identified across all three vegetation associations and in some instances some species occurred in more than one association. The silver sage vegetation association had four, needle and thread had 11, and green ash draw vegetation associations had three increaser species. Increaser grass species were slender wheatgrass (*Elymus trachycaulus*), Kentucky bluegrass, green needlegrass, smooth brome grass, *Agropyron* spp., junegrass (*Koeleria pyramidata*), little bluestem (*Schizachyrium scoparium*) and an unknown

Carex species. Increaser forb species were fern spp., prairie coneflower (*Ratibida columnifera*), purple prairie clover (*Dalea purpurea*), toadflax (*Comandra umbellata*), and leafy spurge. Golden current (*Ribes odoratum*) and western snowberry (*Symphoricarpos occidentalis*) were the two increaser shrub species and Rocky Mountain juniper (*Juniperus scopulorum*) was the only tree species (Increaser species are listed in Appendix A, Table A-2).

Vegetation Association Similarity and Dissimilarity

Similarity coefficients (J) among sites across all three vegetation associations were between 0.24 and 0.38, and baseline values ranged between 0.25 and 0.39 (Table 3.5). Dissimilarity coefficients (D_{ij}) among the sites across all three vegetation associations were between 0.53 and 0.78 with baseline values ranging between 0.52 and 0.75 (Table 3.5).

Species assemblages among sites were similar across all vegetation associations (no significant differences $p \geq 0.10$ detected between the similarity and dissimilarity coefficients) (Table 3.5). Non-infested and bio-control sites were also similar in species assemblages (no significant differences between similarity and dissimilarity coefficients) (Table 3.5). Differences in species assemblages were detected (p values ranged between 0.10 to 0.01) between bio-control and infested sites in the silver sage 100 m² plots and the needle and thread 100 m² and 1000 m² plots (Table 3.5). A strong response between infested and bio-control sites was recorded within the 1 m² cover plots (D_{ij}) in the needle and thread vegetation sites. Differences among species assemblages were observed between the non-infested and infested sites in the silver sage 100 m² and green ash draw 1000 m² plots. Removing low frequency species (less than 17%) for all sites within the

Table 3.5. Similarity (J) and dissimilarity coefficients (D_{ij}) for extant vegetation composition for silver sage, needle-and-thread and green ash draw vegetation associations for non-infested (NI), infested (IF), and bio-control (BC) sites in South Unit of Theodore Roosevelt National Park, ND. Leafy spurge species occurrence and average percent cover were removed from data set. Jaccard's coefficient (J) was calculated for 1000 m² and 100 m² plots and Bray Curtis coefficient (D_{ij}) was calculated using average percent cover. Baseline coefficients reflect the average (dis)similarity among replicates within each site.

Silver sage						
Site comparisons	1000 m ²		100 m ²		1 m ²	
	Baseline	J	Baseline	J	Baseline	D_{ij}
NI vs. IF vs. BC	0.30	0.30	0.31	0.28	0.54	0.54
NI vs. IF	0.32	0.32	0.33	0.31*	0.55	0.57
NI vs. BC	0.28	0.26	0.28	0.27	0.52	0.53
BC vs. IF	0.31	0.31	0.31	0.28*	0.54	0.54

Needle-and-thread						
Site comparisons	1000 m ²		100 m ²		1 m ²	
	Baseline	J	Baseline	J	Baseline	D_{ij}
NI vs. IF vs. BC	0.35	0.34	0.29	0.29	0.60	0.62
NI vs. IF	0.38	0.38	0.33	0.31	0.56	0.56
NI vs. BC	0.32	0.30	0.25	0.24	0.63	0.64
BC vs. IF	0.35	0.30***	0.30	0.28*	0.60	0.68***

Green ash draws						
Site comparisons	1000 m ²		100 m ²		1 m ²	
	Baseline	J	Baseline	J	Baseline	D_{ij}
NI vs. IF vs. BC	0.38	0.36	0.29	0.29	0.73	0.74
NI vs. IF	0.38	0.34**	0.31	0.31	0.71	0.71
NI vs. BC	0.39	0.37	0.30	0.30	0.74	0.74
BC vs. IF	0.38	0.37	0.30	0.30	0.75	0.78

* significant differences detected between treatments at $p \leq 0.10$, ** significant at $p \leq 0.05$, *** significant at $p \leq 0.01$

three vegetation associations prior to analyses (data not shown) resulted in similar similarity and dissimilarity coefficients to those presented in Table 3.5.

Seed Bank Analyses

Seed Bank Species Richness

In general, the persistent and dormant seed banks were more species rich than the two transient seed banks when compared across all vegetation associations (Table 3.6). The transient late season seed bank was also more rich than the transient early seed bank (Table 3.6). Total numbers of species documented within each seed bank fraction by site and vegetation association are listed in Appendix A, Tables A-3, A-4, and A-5. Bio-control sites were similar in richness to non-infested sites in silver sage and green ash draw vegetation associations for total seed bank species, whereas bio-control sites in the needle and thread vegetation association had higher species richness than non-infested sites (Table 3.6). Infested sites in the silver sage vegetation association persistent seed bank were higher in richness ($p \leq 0.05$) than bio-control sites (Table 3.6). Non-infested sites in the needle and thread vegetation association were lower ($p \leq 0.05$) than infested and bio-control sites in the transient late and total seed banks.

Seed Bank Composition

Forb seed constituted a larger proportion of seed banks compared to other herbaceous and woody species across all vegetation associations (Table 3.7). For a complete list of compositional components in seed bank fractions within each vegetation association see Appendix A, Table A-6. Forbs, graminoids shrubs, trees, non-native forbs and non-native grass were similar among infested, bio-control, and non-infested sites ($p \geq 0.05$) in the silver sage and green ash draw vegetation associations (Table 3.7).

Table 3.6. Mean seed bank richness and standard deviations () for each seed bank fraction for silver sage, needle-and-thread, and green ash draw vegetation associations within non-infested (NI) infested (IF), and bio-control (BC) sites. Transient seed banks consisted of seedlings germinated from surface litter (collected Sept 2001 = transient late, and June 2002 = transient early) in the South Unit of Theodore Roosevelt National Park, ND. Persistent seed bank consisted of seedlings germinated from soil core samples. Dormant seed bank consisted of remaining un-germinated viable seed from the persistent seed bank.

Sites	Mean seed bank richness				
	Transient late	Transient early	Persistent	Dormant	Total seed bank ¹
Silver sage					
NI	8 (5.0) ^{a2}	3 (1.7) ^a	12 (6.4) ^{ab}	15 (6.6) ^a	9 (6.9) ^a
IF	9 (3.6) ^a	6 (2.2) ^a	12 (3.8) ^a	11 (3.0) ^a	10 (3.7) ^a
BC	7 (3.9) ^a	5 (2.3) ^a	7 (2.0) ^b	12 (2.3) ^a	8 (3.5) ^a
Needle-and-thread					
NI	4 (1.4) ^b	4 (2.7) ^a	8 (5.8) ^a	9 (5.3) ^a	6 (4.5) ^a
IF	9 (3.9) ^a	5 (1.0) ^a	10 (4.2) ^a	12 (4.5) ^a	10 (4.4) ^b
BC	9 (3.3) ^a	5 (2.8) ^a	11 (2.5) ^a	14 (3.1) ^a	10 (4.3) ^b
Green ash draw					
NI	4 (5.4) ^a	7 (1.6) ^a	13 (4.3) ^a	12 (4.3) ^a	11 (4.7) ^a
IF	9 (2.6) ^a	3 (1.3) ^b	8 (4.8) ^b	10 (4.8) ^a	7 (4.1) ^b
BC	9 (2.5) ^a	6 (2.1) ^a	15 (3.9) ^a	15 (3.9) ^a	12 (4.9) ^a

¹Total seed bank values represent sum of individual species across all seed bank fractions (transient late, transient early, persistent and dormant)

²Significant difference detected at $p \leq 0.05$ using the Kruskal-Wallis Test. Similar letters within a column represent no significant differences within each vegetation association and seed bank type.

Non-native grasses were higher in bio-control sites compared to non-infested sites ($p \leq 0.05$) in the needle and thread association, however this difference was attributed to one species.

Common Seed Bank Species

Species most commonly found (frequency of occurrence equal to 50% or more across the replicates) in each seed bank are listed in Appendix A, Table A-7, A-8, and A-9. A total of 23, 25 and 30 commonly occurring species were documented in the silver sage, needle and thread and green ash draw vegetation associations, respectively.

Chenopodium species occurred in infested, non-infested, and bio-control seed banks across all three vegetation associations. Species with the highest mean seed densities across all three vegetation associations were yellow sweetclover (*Melilotus officinalis*), leafy spurge and *Chenopodium* species.

Silver sage seed bank

There were 17 common forbs (74% of the common seed bank species) and six common grasses (26% of the common seed bank species in the silver sage vegetation association seed bank (Table A-7). Four of the forb species were non-native while three of the grass species were non-native species. The non-infested seed bank contained 15 species (73% forbs, 13% graminoids, and 14% non-native forbs and non-native grass). The infested seed bank contained 14 species (72% forbs, and 28% non-native forbs and non-native grass). The bio-control seed bank contained 10 species (70% forbs and 30% non-native forbs and non-native grass). *Chenopodium* species, rough false pennyroyal (*Hedeoma hispida*) and Kentucky bluegrass were present in at least one seed bank fraction across all sites. Fourteen species were found in the dormant fraction of the non-

Table 3.7. Mean seed bank richness (standard deviations) by growth form in non-infested, infested, and bio-control sites for the silver sage, needle-and-thread and green ash draw vegetation associations located in the South Unit of Theodore Roosevelt National Park, ND. Seed bank species consists of all seeds germinated and identified in a greenhouse emergence study and all remaining ungerminated seeds remaining in soil core samples collected in Sept 2001 and June 2002.

Site	Forbs	Graminoids	Trees	Non-native forbs	Non-native grasses
Silver sage richness by growth form*					
NI	13.3a (8.45)	2.8a (1.72)	0 (0.00)	4.0a (2.28)	2.0a (1.10)
IF	13.0a (2.83)	4.3a (2.34)	0 (0.00)	3.2a (1.72)	2.2a (1.32)
BC	10.3a (3.88)	4.7a (4.42)	0 (0.00)	2.3a (1.63)	1.2a (0.41)
Needle-and-thread richness by growth form*					
NI	9.8a (5.53)	4.3a (2.50)	0 (0.00)	2.3a (1.21)	0.0a (0.00)
IF	10.7a (2.66)	6.2a (2.64)	0 (0.00)	4.2a (2.14)	0.5a (0.55)
BC	13.0a (3.33)	5.8a (1.47)	0 (0.00)	4.5a (2.17)	0.7b (0.52)
Green ash draw richness by growth form*					
NI	16.3a (4.41)	3.7a (1.97)	1.0 (0.00)	3.7a (1.03)	4.3a (1.97)
IF	11.8a (5.91)	3.8a (1.89)	0.8 (0.50)	1.8a (0.50)	3.0a (0.00)
BC	17.3a (4.72)	4.7a (2.34)	0.8 (0.41)	3.5a (0.55)	3.8a (1.33)

*Letters in common within a row by vegetation association denote no significant difference detected at $p \geq 0.05$ using Kruskal-Wallis rank test.

infested sites followed by nine species in the bio-control sites. Leafy spurge and Kentucky bluegrass seed comprised the largest proportion of the transient and persistent seed banks, whereas yellow sweetclover and *Chenopodium* species comprised the largest proportion of the dormant seed bank.

Needle and thread seed bank

There were 17 common forbs (68% of the common seed bank species) and eight common grass (32% of the common seed bank species) in the needle and thread vegetation seed bank. Six of the forbs were non-native species and one grass was a non-native species. The non-infested seed bank contained eight species (63% forbs, 25% graminoids and 13% non-native forbs and grass). The infested seed bank contained 16 species (44% forbs, 31% graminoids, and 25% non-native forbs and grass). The bio-control seed bank also contained 16 species (50% forbs, 19% graminoids, 31% non-native forbs and grass). Seeds of needle and thread were common to all sites.

Green ash draw seed bank

There were 20 common forbs (67% of the common seed bank species, eight common graminoids (27% of the common seed bank species) and one tree species in the green ash draw vegetation seed bank. Three of the forbs were non-native species. The infested seed bank consisted of nine species (33% forbs, 33% graminoids, 11% trees and 27% non-native forb and grass). The bio-control seed bank consisted of 21 species (43% forbs, 9% graminoids, 5% trees, and 43% non-native forbs and grass). *Chenopodium* species were common to all seed bank fractions, and leafy spurge and Kentucky bluegrass had the highest mean seed densities.

The Leafy Spurge Seed Bank and Other Non-native Species

Leafy spurge seed densities (total seed bank) in infested and bio-control sites were similar ($p \geq 0.05$) across all vegetation associations and were higher than seed densities in non-infested sites except in green ash draw vegetation associations (Fig. 3.1). Most leafy spurge seed was found in the persistent fraction of the seed bank for all three vegetation associations (Fig. 3.2). Leafy spurge seed was nearly absent in the dormant fraction of the seed bank as defined in this study among all sites in the silver sage and green ash draw vegetation associations. The highest number of leafy spurge seeds documented within a single site was 2,158 seeds/m² collected in a green ash draw infested plot (individual site data not shown). Comparatively, silver sage had higher leafy spurge seed densities in the infested and bio-control sites, than in the needle and thread and green ash draw vegetation associations (Figure 3.1).

Eleven species were identified as major weed species (species occurrence in more than one vegetation type and seed density of more than 20 seed/m²) occurring among the sites across the vegetation associations (Appendix A, Table A-10). An additional 14 species were identified as minor non-native species contributing to seed bank density. Over all vegetation associations, leafy spurge, Japanese brome, yellow sweet clover and Kentucky bluegrass were found in the highest densities. Very few species were significantly different among sites over all vegetation associations. Common burdock (*Articum minus*) seed density (105 seed/m²) was 97% higher in the non-infested sites compared to infested areas in green ash draw vegetation associations ($p \leq 0.05$) and smooth brome mean seed densities (36 seed/m²) was significantly higher in bio-control seed sites compared to infested and non-infested sites (3 seed/m² and 1 seed/m² respectively). Kentucky bluegrass seed density in green ash draw bio-control

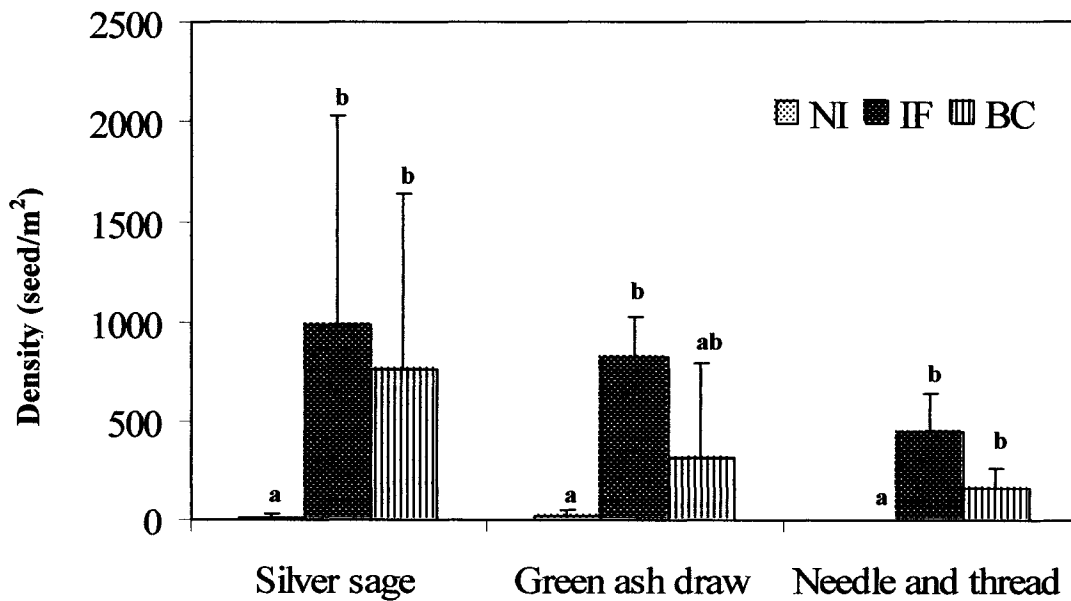


Fig. 3.1. Total seed bank mean seed density (seed/m²) of leafy spurge in non-infested (NI), infested (IF) and bio-control (BC) sites in silver sage, needle and thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Mean seed densities consist of the sum of all seed within seed bank fractions (transient, persistent, and dormant) and averaged over the number of plots. Similar letters within a vegetation association indicate no significant difference at $p \leq 0.05$ using the Kruskal Wallis test. Vertical bars represent standard deviations.

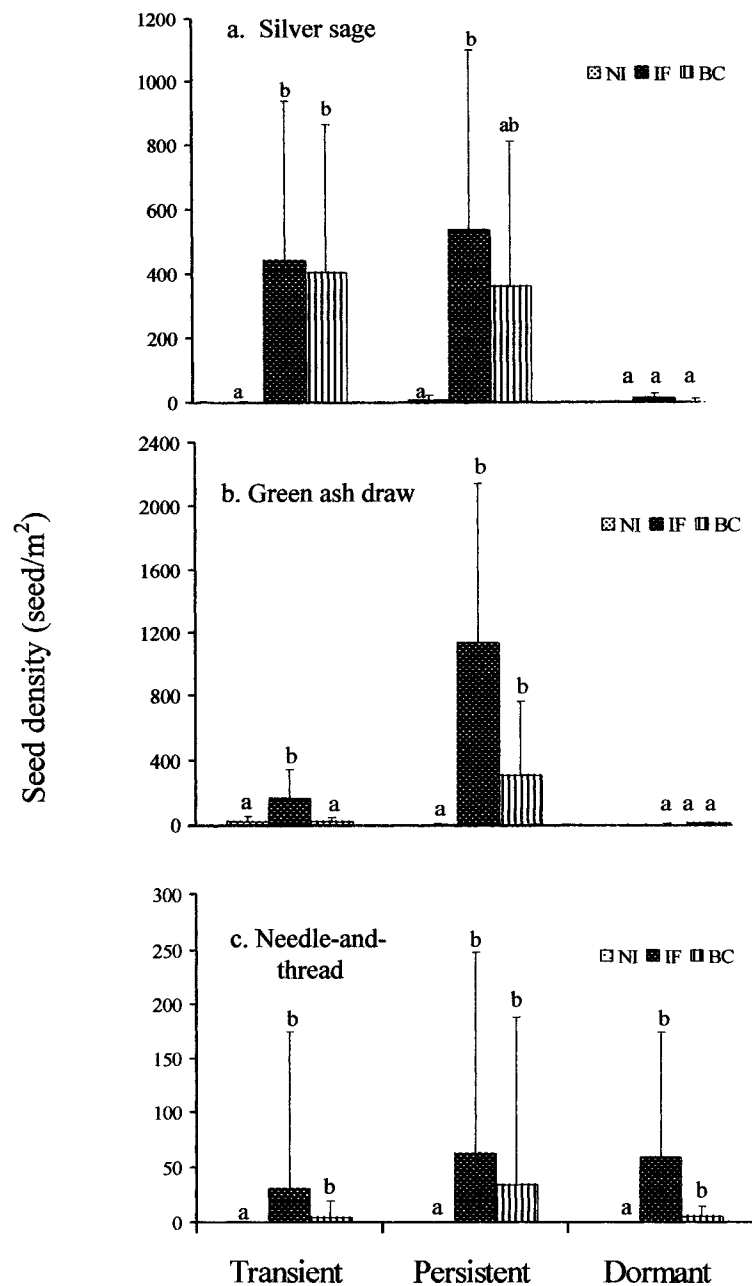


Fig. 3.2 Mean seed density of leafy spurge in the transient, persistent and dormant seed banks in non-infested (NI), infested (IF) and bio-control (BC) sites in silver sage, needle and thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Transient seed banks consisted of seed present in surface litter collected in late summer of 2001 and early summer of 2002. Persistent and dormant seedbanks represent seed present in soil cores collected in fall of 2001. All dormant seed was tested for viability using tetrazolium (AOSA 2002). Thirty, 5 x 10 cm cores were collected from each plot, n = 6 for all samples except for green ash draw infested plots where n = 4. Similar letters within a seed bank fraction indicate no significant difference at $p \leq 0.05$ using the Kruskal Wallis test. Vertical bars represent standard deviations.

sites was 10 fold higher (390 seed/m² vs. 39 seed/m²) than seed densities found in non-infested sites ($p > 0.05$).

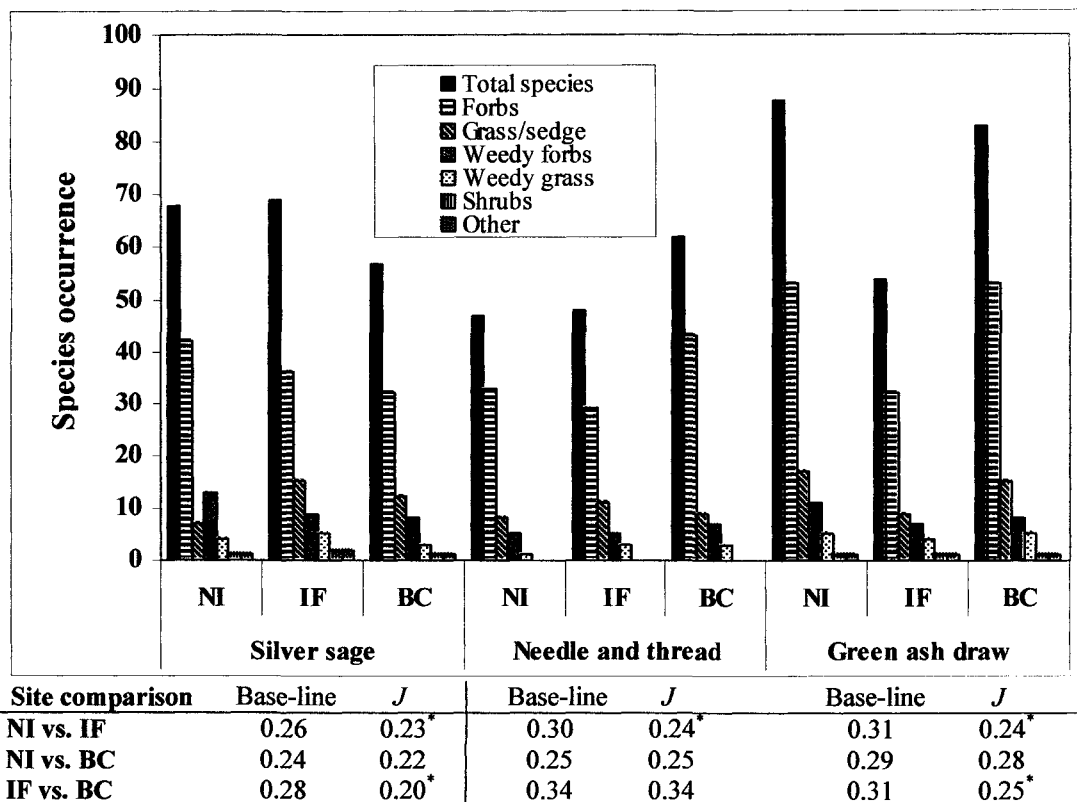
Seed Bank Species Similarity

Similarity coefficients (J) based on species occurrences among non-infested, infested, and bio-control sites ranged between 0.20 to 0.34 across all three vegetation associations (Figure 3.3). No significant differences in similarity coefficients ($p \geq 0.05$) were detected between non-infested and bio-control sites across all vegetation associations and indicate similar species occurrences between those sites.

Extant Species and Seed Bank Species Comparisons

All Extant Vegetation Species vs. Seed Bank Species

Extant species occurrences outnumbered seed bank species occurrences in nearly all sites (Figure 3.4). Jaccard's coefficient between seed bank species occurrences and extant species occurrences ranged between 0.18 to 0.23 for non-infested, infested, and bio-control sites across all vegetation association (Figure 3.4). Baseline coefficients were between 0.31 to 0.43, indicating relatively high level of variability in species occurrences among replicates within sites. Species assemblages of extant vegetation compared to seed bank species were not similar ($p \leq 0.05$) within any site or vegetation association as indicated by mean similarity coefficient (J) (Figure 3.4). To evaluate if seed bank in one site was similar to the vegetation in a different site, for instance if seed bank species in the infested sites were more similar to vegetation in a bio-control site, all combinations of extant species to seed bank species within a vegetation association were tested and no similarities were found ($p \geq 0.05$), (see Appendix A, Table A-11). When comparing all



*Significant differences detected between sites at $p \leq 0.06$.

Figure 3.3. Seedbank species occurrences and Jaccard's baseline (BL) and similarity coefficients (*J*) comparisons for non-infested (NI), infested (IF), and bio-control treatment (BC) sites in the silver sage, needle and thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Jaccard's (*J*) coefficient measures the degree of species similarity between the sites (N vs. IF, N vs. BC, and IF vs. BC). Jaccard's baseline coefficients (BL) reflect the amount of similarity between species among replicates within sites ($n = 6$ for all sites except green ash draw infested sites where $n = 4$) across the sites.

extant species occurrences to all seed bank species occurrences within all replicates, the percentage of shared species were 48 to 52% for silver sage, 37 to 43% for needle and thread, and 38 to 60% for non-infested, infested and bio-control sites in the green ash draw vegetation association (Table 3.8).

Common Extant Species and Seed Bank Species Comparisons

No species assemblage similarities were found between common extant species and seed bank species in any site or vegetation association. Baseline values ranged between 0.49 to 0.64 across all site and vegetation associations indicating greater similarity between replicates (Appendix A, Figure 1). Similarity coefficients between seed bank species occurrences and extant species occurrences ranged between 0.33 to 0.42 for silver sage, 0.26 and 0.36 for needle and thread and 0.21 and 0.29 for green ash draw vegetation association, however no comparisons within a site were significantly different ($p \leq 0.05$). (Appendix A, Figure 1). When comparing all common extant species occurrences to all seed bank species occurrences within all replicates, the percent of shared species were 71 to 82% for silver sage, 56 to 72% for needle and thread, and 50 to 58% for non-infested, infested and bio-control sites in green ash draw vegetation associations (Table 3.8).

Seed present only in the seed bank with no corresponding extant vegetation observed indicate there is potential for an additional three forbs, and two grasses to establish in silver sage, two forbs and one grass in needle and thread, and five forbs, two grasses and one non-native forb in green ash draw bio-control sites (Appendix A, Table A-12). Most of these species are annual or biennial species. Many of the seed of these species may have migrated into the site areas in preparation for future establishment and

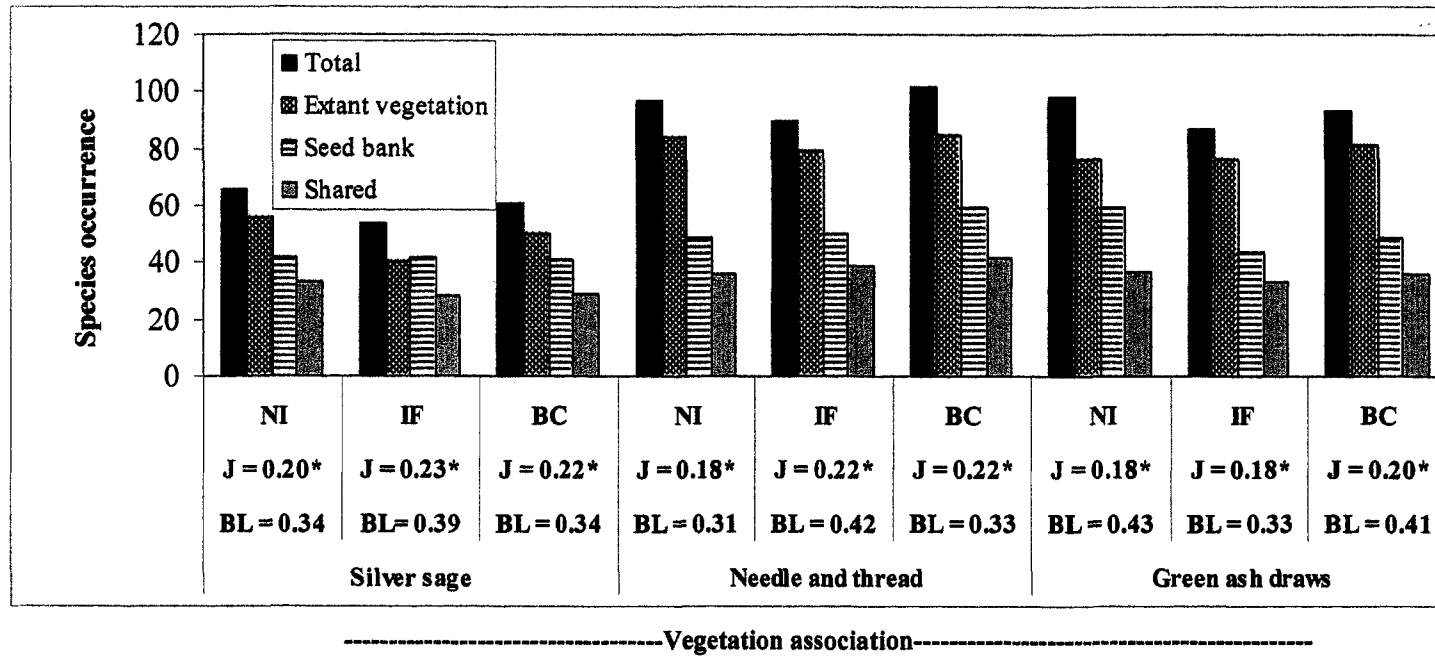


Figure 3.4. Species present in extant vegetation the corresponding seed bank, and the number of species shared in non-infested (NI), infested (IF), and bio-control treated sites (BC) in the silver sage, needle and thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Species with frequencies of 17% or less were removed from comparisons. Jaccard's similarity index (J) indicates the level of similarity between the above ground and the seed bank species. Jaccard's baseline coefficients (BL) reflect the amount of similarity between species among replicates within sites ($n = 6$ for all sites except green ash draw infested sites where $n = 4$) across the sites. * Significant differences were detected between existing vegetation and seed banks at $p \leq 0.05$ for all treatments within each vegetation association

Table 3.8. Percentage of species shared between the extant vegetation and seed banks in non-infested (NI), infested (IF), and bio-control (BC) sites in the silver sage, needle-and-thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND.

	Silver sage			Needle-and-thread			Green ash draw		
	NI	IF	BC	NI	IF	BC	NI	IF	BC
% species shared in extant vegetation species and seed banks ¹	50	52	48	37	43	41	60	38	56
% species shared in 'common' extant vegetation species and seed banks ²	71	82	80	70	56	72	58	55	50

¹Extant vegetation species frequency $\geq 17\%$

²Common extant vegetation species frequency $\geq 67\%$.

were awaiting optimal conditions or have long-lived seed stored within the seed bank (not expressed as extant vegetation). Some of these same species are reported to contribute to seed banks in other vegetation associations while extant vegetation is absent or low in coverage (Goss 1924; Salisbury 1961; Akinsoji 1988; Coffin & Lauenroth 1989; Archibold 1981; Rosburg et al. 1994).

Extant Species Impacted by Leafy Spurge and Seed Bank Availability

Vegetation analyses conducted on the sites showed eight common/sensitive (c/s) and 10 occasional/sensitive (o/s) species that were negatively impacted by leafy spurge infestation. Over 50% (10 species) of these sensitive species had viable seed present in their respective seed banks in infested and bio-control sites indicating that seeds were available for recovery and restoration in these areas. However, in some cases the seed density was below 10 seed/m² (Table 3.9). Eight of the sensitive species listed in Table 3.9 (*Symphoricarpos occidentalis*, *Allium textile*, *Achillea millefolium*, *Krascheninnikovia lanata*, *Opuntia* spp., *Polygonium douglasii*, *Potentilla pennsylvanica* and *Psolrlea argophylla*) contain 0 to 1/seed m² in the seed banks of infested, bio-control or non-infested sites.

Extant Vegetation in Non-Infested Sites and Seed Bank Availability in Bio-control and Infested Sites.

Vegetation analyses showed 20, 28, and 33 commonly occurring species (frequency of 67% or more) in the non-infested sites of the silver sage, needle and thread and green ash draw vegetation associations, respectively. To determine the potential of common species to recover in the infested and infested with bio-control treated sites to similar species composition as found in the non-infested areas, the number of species common in the extant vegetation were compared with their occurrences in the infested

Table 3.9. Extant vegetation species affected by leafy spurge infestation and corresponding seed bank plot frequencies, seed densities (seed/m²) and standard deviations (±) in non-infested, infested, and bio-control sites in silver sage, needle-and-thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND.

Extant species	Association ¹	Non-infested			Bio-control			Infested		
		Extant veg. Freq ²	Seed bank		Extant veg. Freq ²	Seed bank		Extant veg. Freq ²	Seed bank	
			Freq ²	Density (seed/m ²)		Freq ²	Density (seed/m ²)		Freq ²	Density (seed/m ²)
Common species³										
<i>Amaranthus albus</i> (f) ⁴	GA	67	67	103 ± 79.8	50	83	26 ± 20.0	0	50	27 ± 20.2
<i>Artemisia ludoviciana</i> (f)	NT	67	33	4 ± 9.5	50	50	2 ± 2.1	0	17	1 ± 1.6
<i>Dalea purpurea</i> (f)	NT	67	17	2 ± 2.5	50	33	6 ± 10.2	33	33	3 ± 4.7
<i>Echinacea angustifolia</i> (f)	NT	83	17	1 ± 1.5	67	0	0	33	0	0
<i>Euphorbia spathulata</i> (f)	GA	67	50	9 ± 11.1	17	50	8 ± 11.8	25	33	17 ± 27.1
<i>Euphorbia spathulata</i> (f)	SS	83	100	76 ± 66.4	67	83	128 ±	33	50	37 ± 65.8
<i>Linum lewisii</i> (f)	NT	83	50	0 ± 0.5	50	83	0 ± 0.4	33	0	0
<i>Poa pratensis</i> (wg)	NT	67	33	3 ± 6.2	50	50	31 ± 52.1	0	33	4 ± 6.2
<i>Syphoriocarpos occidentalis</i> (s)	NT	83	0	0	67	0	0	33	0	0
Occasional species³										
<i>Allium textile</i> (f)	SS	33	0	0	17	0	0	0	0	0
<i>Achillea millefolium</i> (f)	NT	50	0	0	50	0	0	0	0	0
<i>Krascheninnikovia lanata</i> (s)	SS	33	0	0	0	0	0	0	0	0
<i>Collomia linearis</i> (f)	SS	50	50	7 ± 3.5	17	5	5 ± 7.5	0	66	9 ± 20.5
<i>Galium aparine</i> (f)	SS	33	33	1 ± 2.8	33	33	2 ± 1.3	0	17	0 ± 0.6
<i>Lithospermum incisum</i> (f)	SS	33	17	1 ± 2.5	33	0	0	0	17	1 ± 2.8
<i>Opuntia</i> species (f)	SS	33	0	0	17	0	0	0	0	0
<i>Polygonium douglasii</i> (f)	SS	33	0	0	0	0	0	0	0	0
<i>Potentilla pensylvannica</i> (f)	SS	33	0	0	17	0	0	0	0	0
<i>Psoralea argophylla</i> (f)	SS	50	0	0	17	0	0	0	0	0

¹ Vegetation associations: GA = green ash draw, NT = needle-and-thread, and SS = silver sage.

² Extant vegetation frequencies based on 1000 m² plots. Seed bank frequencies and densities based on transient, persistent, and dormant fractions combined where n = 6 for all frequency and density data except for green ash draw infested plots were n = 4.

³ Common/sensitive were extant vegetation species found to be common in the non-infested sites yet reduced by 50% or more; occasional/sensitive species were extant vegetation species that occur within the non-infested plots at a frequency of 34-50% yet were absent in the infested sites.

⁴ f = forb, s = shrub, wg = non-native grass

and infested with bio-control treated seedbanks and are presented in Table 3.10. The density of leafy spurge seed is also presented in Table 3.10 to give an indication of potential competition between leafy spurge and the native vegetation commonly found in the non-infested areas. In the silver sage vegetation association, 75 and 80% of the 20 commonly occurring extant species were found in the infested and bio-control treated seed banks (Table 3.10). In the needle and thread vegetation association, 50 and 54% of the 28 commonly occurring extant species were found in the infested and bio-control treated seed banks, respectively (Table 3.10). And in the green ash draw vegetation association 58% of the 33 commonly occurring extant species were found in both infested and bio-control seedbanks (Table 3.10).

Table 3.10. Comparison between the number of commonly occurring extant vegetation species (frequency of 67% or more) in the non-infested extant vegetation sites to identical species found in the seed bank in non-infested (NI), infested, (IF) and bio-control (BC) sites in the silver sage, needle-and-thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Mean leafy spurge seed density (seed/m²) is also presented for each site within vegetation associations.

Vegetation association	Non-infested extant vegetation (common species)	% species found in seed bank			Mean leafy spurge seed density (seed/m ²)		
		NI	IF	BC	NI	IF	BC
Silver sage	20	85	75	80	8	931	724
Needle-and-thread	28	61	50	54	0	447	164
Green ash draw	33	55	58	58	17	822	310

CHAPTER 4: DISCUSSION

Vegetation

I found no differences in mean species richness or diversity among sites. Conversely, Butler and Cogan (2004) reported significant reductions in species richness between non-infested and infested sites in silver sage and needle and thread vegetation associations in the Park. Mean species richness in my study was 200 to 375% higher than those reported by Butler and Cogan (2004). Sampling plot size and number of replications may have contributed to variability between the two studies. Butler & Cogan (2004) used 10 m x 10 m plots and 4-12 replicates. The modification of Modified Whitaker method in my study was 20 m x 50 m plots and I used 4-6 replicates. The Modified Whitaker method is shown to significantly improve the representation of plant species on a site compared with other more traditional plot techniques such as Parker and Daubenmire methods (Stohlgren et al. 1998). As noted by Butler and Cogan (2004), it is important to note that species richness is a relatively easy method to convey information to various audiences, but caution must be exercised when interpreting reductions in species richness in response to heavy infestation of invasive plants within and among vegetation associations. Infrequent species may be missed because of their very nature of being rare, or they may be overlooked because they are obscured by more common plants.

The forb component in my study was reduced by 13-30% across all vegetation associations in bio-control sites compared to non-infested sites. The reduction of

extant forbs in infested and bio-control sites in my study was similar to results found by Butler and Cogan (2004) and Butler et al. (2006). Their research identified 21 common and occasional forb species that were eliminated in leafy spurge infestations within various vegetation associations in TRNP. Four of the same forb species shown to be impacted by leafy spurge infestation identified by Butler & Cogan (2004) were also impacted in my study. Recent studies of a Montana grassland area also indicate significant reductions in forbs in bio-control sites five years after flea beetle release (Butler et al. 2006).

The ability of leafy spurge to invade and alter sites is likely a process involving numerous ecological factors and species specific competitive interactions. For instance, leafy spurge is reported to have allelopathic characteristics (LeTourneau & Heggeness 1957; Selleck 1972; Steenhagen & Zimdahl 1979; Manners 1983) and this may be a factor contributing to the reduced numbers of forbs recorded in both infested and bio-control sites. However, allelopathic effects of leafy spurge were tested on 12 native and introduced grass species in Montana and grasses grown in soil obtained from heavily infested leafy spurgewere not shown to have negative impacts (Baretto & Fay 1981). No published studies report allelopathic effects of leafy spurge on native forb species, however, preliminary tests indicate reductions in seed germination for five native forbs common to the area (unpublished data).

Although my study did not indicate significant differences in graminoid species among sites, Butler and Cogan (2004) and Butler et al. (2006) indicate fewer grass species were impacted by leafy spurge and several species even increased in cover after bio-control release. These results may imply a potential differential response by grasses

and forbs after leafy spurge infestation within an area that may be related to allelopathic characteristics of leafy spurge.

Eighty nine percent of the sensitive species identified in this study as extant species and shown to be impacted by leafy spurge were present in bio-control sites at the time of this study. These results indicate a recovery of sensitive species, however, additional monitoring of these sites should be conducted to evaluate trends for species occurring at the lower frequencies.

Prairie spurge, winterfat, and knotweed were shown to have no or a low occurrence in bio-control sites compared to infested sites. It is unknown if flea beetle host specificity testing has been conducted on these three species, however, native plants closely related ecologically and taxonomically to the target species are considered to be the most threatened by bio-control agent host shifts (Pemberton 2000). *Euphorbia robusta*, a consubgeneric and sympatric with leafy spurge, and known to occur in the area, was recently evaluated for flea beetle impacts (Wacker 2004). The potential for flea beetles to host-shift to *E. robusta* was determined to be low because of differences in growth habit and root morphology between *E. robusta* and leafy spurge. Prairie spurge, also within the Euphoribcaea, is an annual species that may warrant further investigation related to non-target feeding by adult flea beetles used for bio-control, however it is probable that flea beetles may not be capable of completion of their life cycle on an annual species. Winterfat was sporadically distributed within the sites and across the landscape (personal observation) and frequency variation between sites may be a result of variability across the landscape. Knotweed is an annual species that may vary with

frequency caused by temporal and spatial seed distributions often attributed to annual species (Baskin & Baskin 1998) and is not likely to be impacted by flea beetles.

Observed low baseline similarities (J) and dissimilarities (D_{ij}) likely reflect the environmental heterogeneity associated with badlands type topography. Comparisons of species assemblages and relative cover J and D_{ij} between non-infested and bio-control sites indicate sites are similar.

Green ash draw sites in my study were variable. Some draws were steep and highly infested with leafy spurge along the outer edges and species diversity appeared to decrease as shading increased within the more dense portions of a site (personal observation), while other draws were less steep and species distributions were more evenly distributed. Non-infested and bio-control species assemblages were shown to be similar and infested and non-infested sites were shown to be dissimilar in green ash draw vegetation associations based on species occurrence. Because green ash draws are highly variable in position across the landscape, contain a much more complex vegetation structure (vertically and horizontally), and site sampling was not as robust as other sites ($n = 4$ in infested sites), the observed difference between non-infested and infested sites may be attributed more to random variation across the sampled sites.

It is important to address the potential for replacement of one invasive species (leafy spurge) for another, especially since flea beetles can reduce leafy spurge stem densities by as much as 80-90% in highly infested areas (Anderson et al. 2000). Data from my study did not indicate an increase in non-native species mean cover or mean richness (other than leafy spurge) in infested or bio-control sites compared to the non-infested sites, however, the number of non-native species in the infested and bio-control

sites increased proportionally in all three vegetation types and may warrant further study to monitor potential increases over time. Non-native species that may be of concern are the noxious weeds Canada thistle, field bindweed, and, of course, leafy spurge.

Additionally, North Dakota considers crested wheatgrass, smooth brome, yellow sweetclover, Japanese brome, and downy brome to be invasive and problematic (North Dakota Dept of Agriculture 2005). All of these species were documented in my study sites.

Butler and Cogan (2004) suggest a strong filtering effect on composition and structure of leafy spurge impacted communities and more recently suggest that the lack of change in forb cover, coupled with significant increases in graminoid cover, further support this effect (Butler et al. 2006). Graminoid species, identified as increasers in my study, comprised 75 and 54% of species in silver sage and needle and thread vegetation associations, respectively (no increaser graminoids were identified in green ash draws). The occurrence of these increaser graminoids in the bio-control sites combined with the reduction in forbs additionally support this filtering effect.

Seed Bank/Vegetation

Community structure and dynamics is affected by propagule availability (Aguiar & Sala 1997; Clark et al. 1999). Several studies support this hypothesis via soil sterilization experiments (Kalamees & Zobel 2002; Luzuriaga et al. 2005), seed addition experiments (Goldberg et al. 2001) and agronomic weed seed bank studies (Wilson et al. 1985; Debaeke 1988). However, seed banks are not static systems and additions and deletions to seed banks are in constant flux based on variations in climate, temporal and

spatial distributions of seed, seed predation, and longevity characteristics of specific seed in the soil (Roberts 1981,1983; 1986; Baskin & Baskin 1998).

A considerable amount of variability was observed across all sites in the extant vegetation and seed bank replications as reported in Jaccard's baseline values. Given these baseline values, and the corresponding Jaccard's similarity coefficients, the use of the seed bank to predict future community species composition at an individual site location may be limited. Other seed bank studies report poor correlations and high levels of dissimilarity between species present in existing vegetation and common species occurring in the seed bank, except in disturbed and early successional communities (Major & Pyott 1966; Thompson & Grime 1979; Rabinowitz & Rapp 1980; Rabinowitz 1981; Fenner 1985; Hassan & West 1986; Thompson 1986; Graham & Hutchings 1988; Coffin & Laurenroth 1989; Bertiller 1992; Kinucan & Smeins 1992; Brown 1998; Tracy & Sanderson 2000).

The low baseline and similarity coefficients between extant vegetation and seed bank species found in my study suggests that seed bank analyses (at the individual site specific level) are limited in their potential to predict future vegetation composition trajectories. However, broad scale management implications can be derived from my seed bank study. These implications include 1) native species richness and compositional differences among sites in different vegetation associations may provide information related to the potential of the infested and bio-control sites to return to levels observed in the non-infested sites; 2) seed bank presence of extant vegetation species shown to be negatively impacted by leafy spurge might provide information related to their conservation; 3) leafy spurge seed densities in seed banks provide information to

assess potential re-occurrence or establishment of leafy spurge in impacted sites, and 4) richness and seed density of undesirable species in seed banks in leafy spurge impacted areas could provide valuable information regarding the potential for substituting one non-native species for another.

Richness and Compositional Differences

Silver sage vegetation association

Total species occurrences over all sites indicate that between 48 to 52% of the existing extant vegetation at each site have seed present in their respective seed banks. These percentages increase to 71-82% over all the sites for the more commonly occurring extant species (frequencies of 67% or more) (Table 3.11). This information provides a general estimate of seed bank species presence within each site. My study also indicates that 75% of the 20 commonly occurring extant vegetation species documented in the non-infested sites are present in the infested and bio-control release sites, indicating a positive indicator for future management of these impacted areas.

Needle and thread vegetation association

I found lower species richness in the transient and total seed banks in the non-infested sites in the needle and thread vegetation association (Table 3.2). This may be caused by the perennial and vegetative reproductive capability of many of the grasses present in the extant vegetation. In general, native grassland seed banks have been reported to contain low numbers of seed species and seed (Rabinowitz and Rapp 1980). A 71% decrease in the number of dispersed seed vs. the number of seed documented in tall grass prairie seed bank was reported by Rabinowitz and Rapp (1980).

Grassland seed banks have also been reported to be more transient than persistent (Coffin & Laurenroth 1989). Conversely, in my study common seed bank species were equally distributed within the persistent and dormant seed bank fractions indicating species are present for future establishment. This observed difference is likely an indication of different test conditions. My study was used to evaluate the total seed bank which included the dormant fraction while Coffin & Laurenroth's (1989) study was conducted to evaluate the emergence of non-cold stratified seed banks over time and the dormant seed bank fraction was not evaluated. On average, between 37 to 43% of the existing extant vegetation per site will have seed present in their respective seed banks. This percentage increases to 56-72% for the more commonly extant species (Table 3.8). My study also indicates that 50-54% of the 28 commonly occurring species in the needle and thread non-infested vegetation association are present in the infested and bio-control sites. These data indicate that there are sufficient seed sources to re-establish vegetation on these impacted areas.

Green ash draw vegetation association

My study indicates seed bank species richness in the early transient, persistent, and total seed bank fractions are reduced in the infested sites in the green ash draw vegetation associations (Table 3.6). Although no differences were observed between sites for the forb component (Table 3.7), it is likely that the forb component is a main contributing factor to species richness reduction (combined site data in appendix B). Green ash draws represent unique vegetative communities that are important wildlife habitats and may serve as corridors for seed dispersal (Wald et al. 2005). Seed banks in green ash draws may be highly diverse because of the multitude of transitory ecological

events that occur and may reflect the presence of species in the extant vegetation that are absent in the seed bank and vice versa. For instance, the presence of litter may have a crucial influence on the availability of sites for seedling establishment as well as seed accumulation (Fenner & Thompson 2005). Multiple ecological factors influence seed bank presence and density in many environments (Baskin & Baskin 1998) and the green ash draws evaluated in my study may have factors such as the accumulation and decomposition of dead leaves and other deciduous tissue, combined with shading effects from tree and shrub species that could modify conditions for seedling establishment on the soil surface or effect long-term persistence in the seed bank. Additionally, Butler et al. (1986) reported variability in vegetation and soil moisture conditions in relation to landscape positions within green ash draws which may also contribute to seed bank species variability. These complex interactions are probably best studied on a species by species case to better understand these relationships.

Only a 4% increase in species shared in the ‘common’ extant vegetation and seed banks, compared to species shared in all extant vegetation and seedbanks, was documented in the green ash draw vegetation associations compared to 26 and 28% in silver sage and needle and thread vegetation associations, respectively (Table 3.12). These results suggest that seed in the green ash draw sites may remain on site as a result of increased litter or reduced potential for seed dispersal via wind caused by the presence of more woody tree and shrub species. My study also indicates that 58% of the 33 commonly occurring species in the green ash draw association are present in the infested and bio-control sites.

Impacted extant species and seed bank presence

Not all species in a community are represented in a seed bank (Oosting & Humphreys 1940; Major & Pyott 1966; Barbour & Lange 1967; Milberg 1992; Milberg 1995) because of various physiological and ecological factors such soil pathogens, predators, seed dormancy and dispersal characteristics, and species primary method of reproduction and life history. My study indicates that 10 of the 18 extant species shown to be negatively impacted by leafy spurge produce a seed bank. Nine of these species also had seed in the infested and bio-control sites indicating seeds were available in the seed bank for future establishment in these impacted areas (Table 3.9). Many of the species that did not have a seed bank reproduce vegetatively as well as by seed, and all are perennial species in the region. These results may indicate that the primary method of reproduction of these species may not rely on seed banks or seed dispersal, or the production of seed may be spatially or temporally variable and not captured in a sampling year.

Seed Present in Seed Bank Yet Absent In Vegetation

Species present in seed banks yet absent in extant vegetation likely represent past ecological conditions, have a pulsed seed input, possess long-lived seed or may only emerge from the seed bank under certain conditions (Rabinowitz 1981). These species could become important in the community after disturbance and their presence may impact future vegetation dynamics. My study indicates that species present in the seed bank, yet absent in the extant vegetation, consist primarily of native forbs and grasses. Forb species identified in the bio-control sites consisted primarily of annual species which may contribute to the future recovery of forb species shown to be reduced in these

areas or could have been missed during surveys caused by early completion of their vegetation state. No non-native species were documented in the seed banks that were not present in the extant vegetation, indicating a reduced threat of invasions by other non-native species in the bio-control sites.

Leafy Spurge Seed Bank

My study indicates leafy spurge seed densities may be on a downward trend in the bio-control treated sites, however, seed densities were not significantly lower than those in infested sites (Figures 3.1, and 3.2). The potential for leafy spurge to produce a substantial seed bank is high. One leafy spurge flower is capable of producing an average of 252 seeds (Bakke 1936) and leafy spurge stem densities as high as 1,000 stems/m² have been documented in infested sites (Selleck et al. 1962). Even after bio-control, the capability of remaining leafy spurge plants to produce a seed bank seems high. Leafy spurge seed has been shown to be dormant immediately after shedding from the mother plant and requires at least 28 days of prechilling at 20°C to break seed dormancy (Foley 2004). These seed therefore carry over from year to year and is the method for retaining a viable seed bank. Leafy spurge seeds are reported to remain viable in the soil seed bank for periods of up to 8 years (Bowes & Thomas 1978). Leafy spurge seed from the persistent seed bank in my study germinated immediately after exposed to optimum growth conditions (after cold stratification) and very few un-germinated seed remained for viability testing from the silver sage and needle and thread seed banks. These results would indicate that leafy spurge seed germinates readily when given optimum conditions, yet also has the ability to remain in the soil for germination

and establishment in future seasons. Leafy spurge seeds that remained within the dormant fraction of my seed bank study were non-viable. These differences are likely caused by the different environmental conditions of each study. Bowes & Thomas (1978) used a field study compared to my greenhouse study. My results further support the highly competitive nature of leafy spurge. Although germination of leafy spurge is reported to be high, seedling survival is reported to be low (20%) (Hanson & Rudd 1933; my study). Even with estimates of low survivability, the highly invasible nature of leafy spurge combined with seed densities equal to those observed in infested sites should alert land managers that the potential for reestablishment of leafy spurge following bio-control treatment could be high and should be monitored to ensure that bio-control agents are still active in the area. If these agents are not active, additional bio-control releases may be warranted to prevent reestablishment of leafy spurge.

Green ash draw infested sites contained high densities of leafy spurge seed, although the draws appeared to be much less infested with leafy spurge than other vegetation associations (personal observation). As previously described, the green ash draw sites were variable and may have ecological conditions that allow for higher accumulations of leafy spurge seed. It may also be possible that the reduced number of sampling sites in the infested areas ($n = 4$) may have been insufficient to represent these sites.

Presence of Non-native Species

My results indicate no differences in seed densities of non-native species among the sites in the silver sage and needle and thread vegetation associations. This indicates

DISSERTATION

**BIOLOGICAL CONTROL AFFECTS NATIVE VEGETATION AND
RECOVERY POTENTIAL IN THEODORE ROOSEVELT NATIONAL PARK,
NORTH DAKOTA**

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that the potential for other non-native species to occupy bio-control release sites may be relatively low. Kentucky bluegrass in green ash draw sites was considerably higher in bio-control sites compared to non-infested sites (390 seed/m² vs. 39 seed/m²) and may require additional monitoring, however, TRNP does not consider this species to be a major threat to the Park at this time (USDI-NPS 2005).

It is notable that Canada thistle was observed in the extant vegetation in many of the bio-control and infested sites, however, little to no seed was found during this sampling period. Canada thistle can produce up to 5,000 seeds per plant and are known to remain dormant in the soil for period of up to 20 years (ITIS 2005). Mature seeds that fall to the ground in late summer can easily germinate immediately after falling from the plant forming a rosette that overwinters and flowers the following summer (ITIS 2005). Canada thistle seed is also known to germinate easily at 20°C (Wilson 1979). It is possible that any seed dispersed in my sites germinated immediately after being shed from the plant, or that the seed within my samples germinated and then died during the first weeks of pre-chilling treatment and therefore were not detectable within my study.

CHAPTER 5: SUMMARY AND CONCLUSIONS

The objectives of my study were to evaluate native species vegetation recovery in areas previously infested with leafy spurge and treated with bio-control agents and to examine the potential of the in-situ seed bank to predict future recovery of native species impacted by leafy spurge. It was hypothesized that the extant and seed bank species in the bio-control sites would more resemble non-infested sites than infested sites, and that seed bank comparisons with extant vegetation would provide an indication of potential future communities in these impacted areas. The results of my study indicate bio-control release areas in the Park are on a positive trend towards recovery. The following major points support this prediction and future research recommendations are offered below:

- No difference in species richness or diversity were observed between non-infested, infested or bio-control sites. Differences observed in my study vs. other studies are more than likely due to variations in temporal and spatial sampling methodologies. However, additional studies using the Modified Whitaker sampling method may prove valuable in assessing questions of maintenance of native plant diversity and monitoring of leafy spurge impacted species.
- Seventeen of the nineteen species (89%) shown to be negatively impacted by leafy spurge, as indicated by reduced frequency in infested sites, were present in extant vegetation bio-control sites. These results indicate that at the time of sampling, these species were present in sites five to seven years after bio-control

release. Additional monitoring of these sites is recommended to evaluate recovery trends in species that were low in frequency.

- Vegetation was similar between bio-control and non-infested sites using similarity indices, however, the ‘filtering effect of leafy spurge on vegetational patterns’ as described by Butler & Cogan (2004) and Butler et al. (in press) indicating potential shifting of individual species in areas receiving bio-control should be investigated in more detail in future research programs. This potential shifting of species would address goals and objective of most conservation management programs designed to maintain and preserve species rich communities that contain species assemblages characteristic to specific vegetation associations. As identified in my and other studies, the forb component is shown to be reduced in these vegetation associations. Future monitoring of my research sites, in association with other long-term research plots within the Park, would address these unanswered questions.
- Low similarity coefficients and high levels of variability were observed between extant vegetation and seed bank species suggesting that seed bank analyses at an individual site specific level may not be a good indicator of present or future community assemblages. However, from a broad scale perspective, my research indicates that between 50 to 75% of the commonly occurring extant species within the non-infested sites had seed present in the infested or bio-control sites.

This finding provides important information related to restoration and recovery of leafy spurge impacted sites.

- Ten of the previously mentioned 19 species shown to be negatively impacted by leafy spurge produce a viable seed bank in their non-infested sites and nine of these ten species also have viable seed present in the bio-control and infested sites.
- Leafy spurge seed densities may be on a downward trend in bio-control sites. However, seed densities were not statistically different from those found in the infested sites even after 5-7 years after flea beetle release. It is recommended that long-term monitoring of bio-control sites, including presence of flea beetles, be conducted to evaluate the potential of re-establishment of leafy spurge and need for additional flea beetle releases. Complimentary research conducted on flea beetle population dynamics and possible feedback mechanisms related to leafy spurge as a food source (Larson & Grace 2004) would help evaluate the potential re-occurrence of leafy spurge in these areas.
- Weedy species seed densities (other than leafy spurge) in bio-control and infested sites were not appreciably higher than those found in non-infested sites. Weedy species are not considered a threat for re-infestation into bio-control areas in the Park at this time.
- Even though seed bank studies are likely to be variable in TRNP and similar communities within the area, due to the heterogeneity of the landscape, the use of

seed bank studies for individual species presence and potential establishment in other disturbed or impacted area might prove valuable to management objectives.

- Preliminary studies indicate possible allelopathic characteristics of leafy spurge that may be contributing to the reduction in forb species found in my study and others (Butler & Cogan 2004). Future research to determine effects on individual species could provide useful information in the restoration potential in other areas impacted by leafy spurge.

In conclusion, this research indicates that the existing vegetation, five to seven years post bio-control release, resembles vegetation in non-infested sites and the seed bank contains seed for potential future establishment of many of the commonly identified species. The results of this study provides information that increases the understanding of vegetational and seed bank changes in response to leafy spurge infestation. This information increases the ability of landowners and managers to establish effective goals and objectives to conserve and protect vegetation resources and provides ecological information applicable to the over all understanding of bio-control treatments after the infestation of invasive species.

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Appendix A

Additional Tables and Figures

Table A-2. Increaser extant species in silver sage, needle-and-thread and green ash draw vegetation association in the South Unit of Theodore Roosevelt National Park, ND. Increasers are defined as extant species shown to increase in frequency (50% or more) or average cover (10% or more) in bio-control compared to non-infested sites. Sites are defined as NI = non-infested, BC = bio-control, and IF = infested.

Silver sage				
Species	-----Percent frequency-----			
	NI	BC	IF	Diff (NI-BC)
<i>Agropyron trachycaulus</i>	0.0	50.0	33.3	-50
<i>Carex</i> spp.	16.7	66.7	33.3	-50
<i>Elymus virginicus</i>	0.0	50.0	16.7	-50
-----Average percent cover-----				
<i>Euphorbia esula</i>	3.1	41.4	41.4	-38.3

Needle-and-thread				
Species	-----Percent frequency-----			
	NI	BC	IF	Diff (NI-BC)
<i>Ratibida columnifera</i>	33.3	83.3	16.7	-50
-----Average percent cover-----				
<i>Bromus inermis</i>	0.0	10.9	0.0	-10.9
<i>Comandra pallida</i>	0.4	30.2	4.3	-29.8
<i>Dalea purpurea</i>	11.2	21.1	14.9	-9.9
<i>Koeleria pyramidata</i>	19.8	68.8	25.9	-49.1
<i>Nasella viridula</i>	100.5	133.0	12.3	-32.5
<i>Schizachyrium scoparium</i>	20.4	70.9	34.7	-50.5
<i>Symphoricarpos occidentalis</i>	38.7	80.5	3.4	-41.8
<i>Poa pratensis</i>	4.7	29.6	0.0	-24.9

Green ash draw				
-Species	-----Percent frequency-----			
	NI	BC	IF	Diff (NI-BC)
Fern spp.	33.3	83.3	25.0	-50
<i>Juniperus scopulorum</i>	50.0	100.0	50.0	-50
<i>Ribes aureum</i>	16.7	66.7	25.0	-50
<i>Toxicodendron rydbergii</i>	33.33	100.0	100.0	-66.6

Appendix A

Additional Tables and Figures

Table A-1. Extant species occurrence and frequencies in green ash draw, needle-and-thread and silver sage vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Extant vegetation field analysis was conducted late June to early July, 2002. Species are denoted by the first three letters of the genus and species name, and key to species is listed in Appendix B, Table B.1.

-----Green ash draw-----				-----Needle-and-thread-----				-----Silver sage-----			
-----Site frequency-----				-----Site frequency-----				-----Site frequency-----			
Species	BC	IF	NI	Species	BC	IF	NI	Species	BC	IF	NI
ace neg	16.7	0.0	16.7	ach mil	50.0	0.0	50.0	ach mil	66.7	66.7	83.3
ach mil	100.0	100.0	83.3	agr smi	83.3	83.3	100.0	agr chr	16.7	0.0	0.0
agr smi	66.7	75.0	83.3	all tex	66.7	50.0	50.0	agr cre	0.0	0.0	16.7
agr tra	33.3	0.0	16.7	and ger	16.7	16.7	0.0	agr cri	16.7	16.7	33.3
all tex	16.7	50.0	83.3	ane can	0.0	33.3	33.3	agr rep	0.0	0.0	16.7
ama alb	50.0	0.0	83.3	ant mic	0.0	0.0	16.7	agr smi	100.0	100.0	83.3
amb tri	0.0	0.0	16.7	ant neg	16.7	33.3	33.3	agr tra	50.0	33.3	0.0
ame aln	16.7	25.0	50.0	ant par	0.0	0.0	16.7	all tex	16.7	0.0	33.3
ane can	16.7	0.0	50.0	ari pur	16.7	0.0	16.7	ama alb	0.0	0.0	16.7
ane cyl	50.0	0.0	16.7	art can	83.3	66.7	50.0	ama lan	16.7	0.0	0.0
ant mic	16.7	0.0	0.0	art dra	16.7	16.7	0.0	amb psi	0.0	0.0	16.7
apo and	33.3	25.0	0.0	art fri	83.3	100.0	100.0	ane cyl	33.3	0.0	0.0
arc min	50.0	25.0	66.7	art lud	66.7	0.0	50.0	ant neg	0.0	0.0	16.7
art can	100.0	100.0	100.0	asc pum	0.0	16.7	0.0	arg cre	0.0	0.0	16.7
art fri	16.7	50.0	33.3	asc vir	16.7	50.0	16.7	art can	100.0	100.0	100.0
art lud	66.7	100.0	83.3	ast ads	0.0	16.7	0.0	art dra	0.0	33.3	33.3
ast ads	0.0	25.0	66.7	ast cra	33.3	16.7	16.7	art fri	50.0	66.7	83.3
ast spp	16.7	25.0	66.7	ast eri	66.7	66.7	83.3	art lud	33.3	100.0	66.7
atr nut	0.0	0.0	16.7	ast gil	0.0	0.0	16.7	art tri	0.0	0.0	16.7
bou gra	16.7	0.0	0.0	ast lae	0.0	0.0	16.7	asc ova	16.7	0.0	0.0
bro ine	50.0	50.0	100.0	ast lot	16.7	16.7	16.7	asc spe	0.0	0.0	16.7
bro jap	0.0	50.0	16.7	ast mis	0.0	33.3	33.3	ast ads	0.0	0.0	16.7
bro tec	0.0	50.0	0.0	ast spp	33.3	33.3	16.7	ast eri	0.0	50.0	33.3
cal can	0.0	25.0	0.0	ast unk #1	16.7	16.7	0.0	ast spp	16.7	0.0	16.7
cal lon	0.0	100.0	0.0	ast unk 1	0.0	16.7	16.7	atr can	0.0	0.0	16.7
cal nut	0.0	0.0	16.7	atr nut	0.0	0.0	16.7	atr nut	0.0	0.0	16.7
cam mic	0.0	25.0	0.0	bou cur	0.0	16.7	0.0	atr vit	16.7	0.0	0.0

Table A-1 continued

car fil	33.3	25.0	0.0	bou gra	100.0	83.3	100.0	bou gra	16.7	33.3	50.0
car gra	16.7	0.0	0.0	bro ine	33.3	50.0	0.0	bou spp	16.7	0.0	0.0
car spp	33.3	25.0	16.7	bro jap	33.3	16.7	33.3	bro ine	33.3	66.7	83.3
car spr	0.0	0.0	16.7	bro tec	16.7	16.7	0.0	bro jap	16.7	83.3	83.3
car sp2	0.0	25.0	0.0	cal lon	50.0	100.0	66.7	bro tec	0.0	16.7	0.0
cel sca	0.0	25.0	0.0	cal nut	16.7	83.3	50.0	cal lon	50.0	66.7	33.3
cer arv	0.0	25.0	0.0	cam mic	16.7	66.7	50.0	cal nut	0.0	0.0	16.7
cer lan	0.0	25.0	16.7	car fil	66.7	83.3	83.3	cam mic	66.7	50.0	83.3
che alb	66.7	75.0	33.3	car spp	33.3	100.0	83.3	car dur	33.3	0.0	0.0
che gig	33.3	25.0	50.0	cer lan	33.3	16.7	50.0	car fil	0.0	16.7	50.0
che lan	0.0	25.0	0.0	che alb	0.0	16.7	0.0	car mic	0.0	16.7	16.7
chr nau	0.0	0.0	16.7	che gig	0.0	16.7	16.7	car spp	66.7	33.3	16.7
cir arv	16.7	50.0	0.0	che lan	0.0	16.7	16.7	car spr	0.0	16.7	0.0
cir und	0.0	25.0	0.0	che lep	33.3	66.7	33.3	cer arv	0.0	16.7	0.0
cle lig	33.3	25.0	16.7	chr vil	16.7	33.3	16.7	cer lan	0.0	0.0	33.3
cle spp	16.7	0.0	0.0	cir und	33.3	66.7	83.3	che alb	0.0	0.0	16.7
cle vir	16.7	50.0	0.0	col lin	16.7	16.7	0.0	che gig	33.3	16.7	0.0
col lin	33.3	0.0	0.0	com pal	16.7	33.3	33.3	che lan	16.7	0.0	16.7
com pal	0.0	0.0	16.7	com rot	0.0	16.7	16.7	che lep	16.7	33.3	33.3
com rot	66.7	25.0	50.0	com umb	16.7	0.0	0.0	che unk 1	0.0	0.0	16.7
com umb	16.7	0.0	0.0	cor viv	0.0	66.7	16.7	chr nau	0.0	16.7	16.7
con arv	0.0	25.0	0.0	dal can	16.7	0.0	0.0	cir und	0.0	0.0	16.7
cor mis	0.0	25.0	0.0	dal pub	0.0	16.7	0.0	cle spp	16.7	0.0	0.0
cra rot	0.0	0.0	16.7	dal pur	50.0	33.3	66.7	col lan	16.7	0.0	50.0
dal cin	16.7	0.0	16.7	den ces	0.0	0.0	16.7	col lin	50.0	33.3	16.7
dal pur	16.7	25.0	33.3	des sop	50.0	83.3	83.3	com pal	0.0	0.0	16.7
des sop	16.7	25.0	0.0	ech ang	66.7	33.3	83.3	con arv	0.0	0.0	16.7
dis tra	0.0	0.0	16.7	ely tra	16.7	0.0	0.0	con can	16.7	0.0	0.0
ech ang	16.7	25.0	16.7	eri fla	33.3	16.7	50.0	dal pub	0.0	16.7	0.0
ely tra	0.0	0.0	16.7	eri pau	0.0	33.3	33.3	dal pur	0.0	0.0	16.7
ely vir	83.3	100.0	83.3	eri spe	0.0	16.7	0.0	des sop	50.0	50.0	83.3
eri spi	16.7	0.0	0.0	eri str	16.7	0.0	33.3	ech ang	33.3	0.0	0.0
eri str	33.3	75.0	66.7	ery asp	50.0	16.7	33.3	ely tra	16.7	16.7	0.0
eup esu	50.0	75.0	16.7	eup esu	83.3	100.0	16.7	ely vir	50.0	16.7	0.0

Table A-1 continued

eup spa	16.7	25.0	83.3	eup spa	50.0	0.0	33.3	ens unk	0.0	0.0	16.7
Fern	83.3	25.0	50.0	fra pen	16.7	0.0	0.0	eri pau	0.0	16.7	0.0
fra pen	100.0	100.0	100.0	fri atr	0.0	16.7	0.0	eri spe	0.0	0.0	16.7
fra ves	33.3	25.0	33.3	gal bor	33.3	0.0	0.0	eri str	0.0	0.0	16.7
fra vir	33.3	25.0	16.7	gau coc	66.7	100.0	83.3	esq spp	0.0	0.0	16.7
gal apa	100.0	75.0	83.3	geu tri	16.7	0.0	0.0	eup esu	83.3	100.0	66.7
gal bor	100.0	75.0	100.0	gly lep	16.7	0.0	0.0	eup spa	66.7	33.3	83.3
gau coc	0.0	0.0	16.7	gut sar	0.0	16.7	0.0	gal apa	33.3	0.0	33.3
geu tri	16.7	0.0	16.7	hed his	16.7	50.0	0.0	gal bor	50.0	0.0	16.7
gly lep	16.7	50.0	0.0	hel ann	16.7	0.0	0.0	gau coc	16.7	0.0	16.7
gut sar	0.0	0.0	16.7	hel spp	83.3	83.3	83.3	gly lep	33.3	33.3	16.7
hed his	0.0	25.0	0.0	hym acc	16.7	0.0	16.7	gri squ	33.3	16.7	0.0
hel ann	16.7	25.0	0.0	jun hor	16.7	16.7	33.3	hed his	0.0	16.7	33.3
heu ric	16.7	25.0	16.7	jun sco	33.3	0.0	0.0	hel ann	0.0	16.7	16.7
hor jub	0.0	0.0	16.7	koe mac	16.7	0.0	16.7	hel rig	16.7	16.7	0.0
hum lup	0.0	0.0	50.0	koe pyr	66.7	100.0	66.7	hel spp	16.7	16.7	50.0
jun com	50.0	25.0	50.0	kra lan	16.7	0.0	0.0	hor jub	0.0	16.7	16.7
jun hor	50.0	0.0	16.7	lac obl	66.7	100.0	66.7	jun sco	50.0	16.7	33.3
jun sco	100.0	50.0	66.7	lac ser	16.7	16.7	16.7	koe mac	50.0	16.7	33.3
koe mac	33.3	75.0	16.7	lap occ	0.0	16.7	16.7	lac obl	50.0	33.3	50.0
kra lan	0.0	25.0	0.0	lep den	0.0	33.3	0.0	lac ser	33.3	33.3	0.0
lac obl	83.3	100.0	100.0	les lud	0.0	33.3	16.7	lap occ	0.0	0.0	16.7
lac ser	33.3	25.0	16.7	lia pun	33.3	100.0	66.7	lap rod	0.0	0.0	16.7
lep den	0.0	25.0	0.0	lin lew	50.0	33.3	83.3	lep den	33.3	50.0	50.0
lin lew	16.7	0.0	50.0	lin per	83.3	50.0	50.0	lep occ	0.0	16.7	50.0
lin lew	33.3	50.0	50.0	lin rig	16.7	0.0	0.0	lin lew	0.0	0.0	16.7
lin per	33.3	25.0	16.7	lip den	16.7	33.3	33.3	lin per	50.0	33.3	50.0
lit inc	0.0	25.0	0.0	lit inc	33.3	66.7	66.7	lin rig	0.0	16.7	0.0
lys cil	50.0	75.0	50.0	lyg jun	16.7	100.0	50.0	lip den	0.0	0.0	16.7
mel off	66.7	100.0	66.7	lys cil	16.7	0.0	0.0	lit inc	33.3	0.0	33.3
mon fis	83.3	50.0	66.7	mel off	50.0	16.7	50.0	lot pur	0.0	0.0	16.7
muh spp	0.0	0.0	16.7	muh cus	16.7	0.0	0.0	lyg jun	0.0	33.3	16.7
one ser	0.0	0.0	0.0	muh spp	0.0	33.3	33.3	mel off	66.7	100.0	66.7

Table A-1 continued

ory hym	0.0	16.7	0.0	66.7	16.7	mon fis	0.0	0.0	16.7
ory mic	33.3	50.0	16.7	0.0	16.7	opu pol	16.7	0.0	0.0
orz mic	33.3	33.3	0.0	0.0	16.7	opu spp	16.7	0.0	33.3
osm lon	16.7	0.0	66.7	83.3	100.0	ort lut	0.0	0.0	16.7
oxa str	0.0	16.7	50.0	0.0	33.3	ory hym	0.0	16.7	33.3
par vit	0.0	0.0	0.0	16.7	0.0	pla pat	0.0	16.7	33.3
phl hoo	0.0	16.7	0.0	0.0	16.7	poa ann	16.7	16.7	0.0
pla pat	0.0	0.0	16.7	33.3	16.7	poa com	16.7	0.0	0.0
poa can	0.0	0.0	50.0	16.7	16.7	poa pra	100.0	100.0	100.0
poa pra	100.0	83.3	0.0	0.0	16.7	poa spp	33.3	0.0	0.0
pol alb	0.0	16.7	66.7	33.3	50.0	pol alb	0.0	0.0	16.7
pol bif	0.0	0.0	50.0	0.0	66.7	pol con	33.3	66.7	50.0
pol con	50.0	25.0	0.0	0.0	0.0	pol dou	0.0	0.0	33.3
pot arc	0.0	16.7	66.7	100.0	66.7	pop del	33.3	16.7	0.0
pot arg	16.7	0.0	0.0	16.7	16.7	pot pen	16.7	0.0	33.3
pot fru	16.7	0.0	33.3	33.3	50.0	pru vir	66.7	33.3	50.0
pot pen	16.7	0.0	16.7	16.7	33.3	pso arg	16.7	0.0	50.0
pru ame	16.7	0.0	50.0	66.7	33.3	pso esc	0.0	0.0	16.7
pru pen	0.0	25.0	0.0	50.0	50.0	rhu aro	50.0	16.7	16.7
pru vir	100.0	83.3	83.3	16.7	33.3	rib odo	50.0	50.0	16.7
pso arg	33.3	0.0	50.0	50.0	16.7	rib ord	0.0	0.0	16.7
pso esc	16.7	16.7	16.7	0.0	0.0	rib set	0.0	0.0	16.7
ran abo	16.7	50.0	33.3	50.0	50.0	ros spp	0.0	66.7	50.0
ran arb	16.7	0.0	33.3	16.7	33.3	rush unk#1	16.7	0.0	0.0
rat col	16.7	75.0	83.3	83.3	66.7	sar ver	0.0	0.0	16.7
rhu aro	0.0	0.0	0.0	50.0	0.0	sch sco	33.3	16.7	0.0
rib odo	16.7	16.7	16.7	0.0	0.0	sen spp	0.0	0.0	16.7
ros spp	50.0	33.3	33.3	16.7	16.7	she ara	0.0	16.7	0.0
sal ibe	0.0	0.0	0.0	0.0	0.0	she arg	0.0	0.0	0.0
sch sco	33.3	33.3	83.3	83.3	66.7	smi ste	33.3	33.3	0.0
rhu aro	66.7	100.0	83.3	0.0	0.0	sol mol	16.7	16.7	0.0
rib odo	66.7	25.0	16.7	16.7	33.3	sol spp	50.0	50.0	33.3
rib ord	33.3	75.0	33.3	0.0	16.7	sol mis	0.0	16.7	16.7
rib set	83.3	100.0	16.7	16.7	0.0	sol mol	0.0	0.0	0.0
ros spp	100.0	100.0	83.3	16.7	0.0	sol tri	16.7	16.7	16.7
ros woo	0.0	0.0	16.7	16.7	0.0	sph coc	83.3	50.0	16.7
rub ida	16.7	0.0	16.7	16.7	0.0				
sch sco	0.0	25.0	16.7	83.3	50.0				

Table A-1 continued

urt dio	16.7	0.0	0.0
vic ame	66.7	25.0	66.7
vit vul	16.7	25.0	0.0
Total species	101	100	111
Grand total across all sites		145	143

Table A-2. Increaser extant species in silver sage, needle-and-thread and green ash draw vegetation association in the South Unit of Theodore Roosevelt National Park, ND. Increasers are defined as extant species shown to increase in frequency (50% or more) or average cover (10% or more) in bio-control compared to non-infested sites. Sites are defined as NI = non-infested, BC = bio-control, and IF = infested.

Silver sage				
Species	Percent frequency			
	NI	BC	IF	Diff (NI-BC)
<i>Agropyron trachycaulus</i>	0.0	50.0	33.3	-50
<i>Carex</i> spp.	16.7	66.7	33.3	-50
<i>Elymus virginicus</i>	0.0	50.0	16.7	-50
Average percent cover				
<i>Euphorbia esula</i>	3.1	41.4	41.4	-38.3

Needle-and-thread				
Species	Percent frequency			
	NI	BC	IF	Diff (NI-BC)
<i>Ratibida columnifera</i>	33.3	83.3	16.7	-50
Average percent cover				
<i>Bromus inermis</i>	0.0	10.9	0.0	-10.9
<i>Comandra pallida</i>	0.4	30.2	4.3	-29.8
<i>Dalea purpurea</i>	11.2	21.1	14.9	-9.9
<i>Koeleria pyramidata</i>	19.8	68.8	25.9	-49.1
<i>Nasella viridula</i>	100.5	133.0	12.3	-32.5
<i>Schizachyrium scoparium</i>	20.4	70.9	34.7	-50.5
<i>Symphoricarpos occidentalis</i>	38.7	80.5	3.4	-41.8
<i>Poa pratensis</i>	4.7	29.6	0.0	-24.9

Green ash draw				
Species	Percent frequency			
	NI	BC	IF	Diff (NI-BC)
Fern spp.	33.3	83.3	25.0	-50
<i>Juniperus scopulorum</i>	50.0	100.0	50.0	-50
<i>Ribes aureum</i>	16.7	66.7	25.0	-50
<i>Toxicodendron rydbergii</i>	33.33	100.0	100.0	-66.6

Table A-3. Seed bank species presence and composition by site within silver sage vegetation association. Sites are denoted as: N = non-infested, IF = infested, BC = bio-control.

Composition	Silver Sage Seed Bank by treatment (n=6, n=36 all Seed banks)														
	---Transient late ¹ ---			---Transient early ¹ ---			-----Persistent ² -----			-----Dormant ³ -----			-----All Seed banks ⁴ -----		
	N	IF	BC	N	IF	BC	N	IF	BC	N	IF	BC	N	IF	BC
Forbs	12	15	9	6	6	8	27	21	16	26	18	17	42	36	32
Graminoids	4	6	5	0	1	2	3	6	5	2	5	5	7	15	12
Shrubs	0	1	0	0	0	0	0	0	0	1	1	1	1	2	1
Trees	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Vines	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
Non-native Forbs ⁵	5	4	5	3	5	4	6	5	4	5	4	4	13	9	8
Non-native Grasses ⁵	3	4	2	2	3	2	4	6	1	0	1	1	4	5	3
Total	24	31	21	11	15	16	38	38	26	34	30	29	68	69	57

¹ Transient seed banks consisted of surface litter collected late summer (late) and early summer (early).

² Persistent seed bank consisted of seedlings emerging from soil cores in a 5 mo. greenhouse emergence study.

³ Dormant seed bank consisted of remaining viable seeds in soil cores after 5 mo. in greenhouse emergence study.

⁴ All seed banks represent all seed bank fractions combined and adjusted for duplication.

⁵ Non-native species determined by North Dakota state coefficients of conservation (Northern Great Plains Quality Assessment Panel 2001).

Table A-4. Seed bank species presence and composition by treatment type within needle-and-thread association. Sites are denoted as: N = non-infested, IF = infested, BC = bio-control. No shrubs, trees, or vine species were documented in any sites.

Composition	Needle-and-thread Seed Bank (n=6, n=36 all Seed banks)														
	---Transient late ¹ ---			---Transient early ¹ ---			-----Persistent ² -----			-----Dormant ³ -----			-----All Seed banks ⁴ -----		
	N	IF	BC	N	IF	BC	N	IF	BC	N	IF	BC	N	IF	BC
Forbs	13	14	12	7	4	10	22	11	24	18	18	23	33	29	43
Graminoids	3	7	6	1	1	2	5	7	8	6	9	7	8	11	9
Non-native Forbs ⁵	3	5	6	5	6	4	5	6	6	3	5	7	5	5	7
Non-native Grasses ⁵	1	3	3	0	1	3	0	0	1	1	0	1	1	3	3
Total	20	29	27	13	12	19	32	24	39	28	32	38	47	48	62

¹ Transient seed banks consisted of surface litter collected late summer (late) and early summer (early).

² Persistent seed bank consisted of seedlings emerging from soil cores in a 5 mo. greenhouse emergence study.

³ Dormant seed bank consisted of remaining viable seeds in soil cores after 5 mo. in greenhouse emergence study.

⁴ All seed banks represent all seed bank fractions combined and adjusted for duplication.

⁵ Non-native species determined by North Dakota state coefficients of conservation (Northern Great Plains Quality Assessment Panel 2001).

Table A-5. Seed bank species presence and composition by treatment type within green ash draw vegetation association. Sites are denoted as: N = non-infested, IF= infested, BC = bio-control.

Composition	Green Ash Draw Seed Bank (n=6 for N and BC, n=4 for IF, n=34 all Seed banks)														
	---Transient late ¹ ---			---Transient early ¹ ---			-----Persistent ² -----			-----Dormant ³ -----			-----All Seed banks ⁴ -----		
	N	IF	BC	N	IF	BC	N	IF	BC	N	IF	BC	N	IF	BC
Forbs	14	10	19	9	4	7	23	13	26	27	20	28	53	32	53
Graminoids	8	5	6	4	2	4	9	3	4	7	3	9	17	9	15
Shrubs	1	0	1	0	0	0	0	0	1	0	1	0	1	1	1
Trees	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1
Vines	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Non-native Forbs ⁵	5	2	5	5	2	4	7	5	7	5	2	3	11	7	8
Non-native Grasses ⁵	4	3	4	2	3	2	3	2	2	0	1	2	5	4	5
Total	33	21	36	21	12	18	43	24	41	39	28	43	88	54	83

¹ Transient seed banks consisted of surface litter collected late summer (late) and early summer (early).

² Persistent seed bank consisted of seedlings emerging from soil cores in a 5 mo. greenhouse emergence study.

³ Dormant seed bank consisted of remaining viable seeds in soil cores after 5 mo. in greenhouse emergence study.

⁴ All seed banks represent all seed bank fractions combined and adjusted for duplication.

⁵ Non-native species determined by North Dakota state coefficients of conservation (Northern Great Plains Quality Assessment Panel 2001).

Table A-6. Mean seed density (seed/m²), standard deviation and frequency in seed bank fractions located in the non-infested, infested and infested with bio-control treatments in the silver sage, needle-and-thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. (n = 6 for all sites except green ash draw infested sites were n = 4). Persistent and dormant seed bank fractions were collected from 30, 5 cm deep x 10 cm wide subsamples per site. Persistent seed densities were determined by seedling emergence in greenhouse studies and the dormant fraction represented the remaining ungerminated seed in the soil samples. Early and late transient seed bank fractions consisted of the collection of the surface litter above the soil samples collected in the persistent and dormant sampling areas. Sampling dates for late transient, persistent and dormant fractions was Sept 2001 and the early transient seed bank collection was June 2002. Species are noted as the first three letters of the Genus and species name and follows Barkley, 1986.

Silver Sage Vegetation Association									
Early Transient Seed Bank									
Species	-----Non-infested-----			-----Infested-----			-----Bio-control-----		
	mean	std	freq	mean	std	freq	mean	std	freq
and occ	9.20	20.53	33.33	11.04	14.59	50.00	0.85	1.90	16.67
art fri	0.00	0.00	0.00	0.00	0.00	0.00	1.70	3.80	16.67
art lud	0.71	1.73	16.67	2.55	3.80	33.33	2.55	2.33	50.00
bro ine	0.71	1.73	16.67	0.85	1.90	16.67	0.00	0.00	0.00
bro jap	0.00	0.00	0.00	8.49	13.09	33.33	0.00	0.00	0.00
cer arv	0.00	0.00	0.00	1.70	3.80	16.67	0.00	0.00	0.00
con can	2.12	5.20	16.67	5.94	5.70	50.00	1.70	3.80	16.67
des sop	1.42	3.47	16.67	0.00	0.00	0.00	2.55	5.70	16.67
eup eus	0.00	0.00	0.00	30.57	38.85	66.67	49.26	46.19	50.00
eup spa	0.71	1.73	16.67	0.00	0.00	0.00	3.40	4.65	33.33
hed his	0.00	0.00	0.00	0.00	0.00	0.00	3.40	7.60	16.67
lac ser	0.00	0.00	0.00	0.85	1.90	16.67	2.55	5.70	16.67
les arn	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
lin per	3.54	8.67	16.67	0.00	0.00	0.00	2.55	3.80	33.33
pas smi	0.00	0.00	0.00	0.00	0.00	0.00	0.85	1.90	16.67
poa ann	0.00	0.00	0.00	0.00	0.00	0.00	2.55	5.70	16.67
poa pra	55.20	74.72	66.67	15.29	3.80	83.33	11.89	14.21	50.00
tar off	7.78	13.27	50.00	7.64	8.17	66.67	0.00	0.00	0.00
tra dub	0.00	0.00	0.00	0.85	1.90	16.67	0.85	1.90	16.67
vul oct	0.00	0.00	0.00	0.85	1.90	16.67	0.00	0.00	0.00

Silver Sage Vegetation Association									
Late Transient Seed Bank									
Species	-----Non-infested-----			-----Infested-----			-----Bio-control-----		
	mean	std	freq	mean	std	freq	mean	std	freq
ach mil	4.25	8.49	16.67	1.13	0.00	0.00	1.42	3.47	16.67
ama alb	1.06	2.12	16.67	0.60	0.00	0.00	0.00	0.00	0.00
and occ	0.00	0.00	0.00	7.14	8.67	16.67	0.00	0.00	0.00
art fri	1.06	2.12	16.67	1.45	1.73	16.67	0.71	1.73	16.67
art lud	1.06	2.12	16.67	4.96	8.35	50.00	0.71	1.73	16.67
ast eri	0.00	0.00	0.00	0.10	1.73	16.67	0.00	0.00	0.00
bro ine	4.25	8.49	16.67	3.00	7.79	33.33	0.00	0.00	0.00

Table A-6 continued

bro jap	22.29	32.04	33.33	9.96	45.16	50.00	0.00	0.00	0.00
cam mic	1.06	2.12	16.67	0.60	0.00	0.00	0.00	0.00	0.00
cer arv	1.06	2.12	16.67	4.49	53.74	16.67	0.00	0.00	0.00
che lep	1.06	2.12	16.67	0.80	2.19	33.33	0.00	0.00	0.00
col lin	0.00	0.00	0.00	0.30	5.20	16.67	2.83	6.93	16.67
con can	0.00	0.00	0.00	4.20	3.55	33.33	11.32	15.11	50.00
des sop	0.00	0.00	0.00	1.66	0.00	0.00	0.71	1.73	16.67
eri str	0.00	0.00	0.00	0.10	1.73	16.67	0.00	0.00	0.00
eup eus	1.06	2.12	16.67	72.98	438.91	83.33	339.70	402.73	83.33
eup spa	3.18	6.37	16.67	2.97	0.00	0.00	1.42	2.19	33.33
hed his	7.43	8.75	33.33	3.73	4.17	66.67	4.95	4.96	66.67
koe mac	4.25	8.49	16.67	1.53	6.93	16.67	5.66	10.29	33.33
lac obl	3.18	6.37	16.67	1.15	3.47	16.67	2.12	3.55	33.33
lac ser	4.25	8.49	16.67	2.74	1.73	16.67	0.00	0.00	0.00
lap occ	0.00	0.00	0.00	0.10	1.73	16.67	0.00	0.00	0.00
lin per	22.29	44.59	16.67	6.65	0.00	0.00	0.00	0.00	0.00
lot pur	0.00	0.00	0.00	0.10	1.73	16.67	0.00	0.00	0.00
mel off	0.00	0.00	0.00	0.00	0.00	0.00	1.42	2.19	33.33
muh rac	0.00	0.00	0.00	0.20	2.19	33.33	2.12	5.20	16.67
nas vir	25.48	48.17	33.33	5.02	0.00	0.00	0.00	0.00	0.00
pas smi	0.00	0.00	0.00	0.69	1.73	16.67	22.65	29.62	66.67
poa pra	31.85	32.25	50.00	30.51	21.72	83.33	14.86	18.94	50.00
pol con	0.00	0.00	0.00	0.30	3.55	33.33	0.00	0.00	0.00
rat col	0.00	0.00	0.00	0.20	3.47	16.67	0.00	0.00	0.00
tar off	4.25	6.01	33.33	7.33	0.00	0.00	2.83	6.93	16.67
thl arv	1.06	2.12	16.67	0.60	0.00	0.00	0.00	0.00	0.00
tra dub	1.06	2.12	16.67	1.87	1.73	16.67	1.42	3.47	16.67
vul oct	1.06	2.12	16.67	1.59	5.14	33.33	0.00	0.00	0.00

Silver Sage Vegetation Association

Early and Late Transient Seed Banks

Species	-----Non-infested-----			-----Infested-----			-----Bio-control-----		
	mean	std	freq	mean	std	freq	mean	std	freq
ach mil	2.83	6.93	16.67	0.00	0.00	0.00	1.42	3.47	16.67
ama alb	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
and occ	8.49	20.80	16.67	12.74	21.82	50.00	1.42	2.19	33.33
art fri	0.71	1.73	16.67	0.71	1.73	16.67	2.12	3.55	33.33
art lud	1.42	2.19	33.33	7.78	9.07	50.00	2.83	3.47	50.00
ast eri	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
bro ine	2.83	6.93	16.67	5.66	9.17	33.33	0.71	1.73	16.67
bro jap	14.86	27.35	33.33	30.43	56.74	50.00	0.00	0.00	0.00
cam mic	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
cer arv	0.71	1.73	16.67	23.35	53.15	33.33	0.00	0.00	0.00

Table A-6 continued

che lep	0.71	1.73	16.67	0.71	1.73	16.67	0.00	0.00	0.00
col lin	0.00	0.00	0.00	2.12	5.20	16.67	2.83	6.93	16.67
con can	2.12	5.20	16.67	7.08	5.80	66.67	12.74	15.66	50.00
des sop	1.42	3.47	16.67	0.00	0.00	0.00	2.83	5.14	33.33
eri str	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
eup eus	0.71	1.73	16.67	351.73	499.15	83.33	380.75	439.69	83.33
eup spa	2.83	5.14	33.33	0.00	0.00	0.00	4.25	5.37	50.00
hed his	4.95	7.79	33.33	4.25	4.65	50.00	7.78	9.84	66.67
koe mac	2.83	6.93	16.67	0.00	0.00	0.00	5.66	10.29	33.33
lac obl	2.12	5.20	16.67	1.42	3.47	16.67	2.12	3.55	33.33
lac ser	2.83	6.93	16.67	1.42	2.19	33.33	2.12	5.20	16.67
les arn	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
lin per	18.40	45.07	16.67	0.00	0.00	0.00	2.12	3.55	33.33
lot pur	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
mel off	0.00	0.00	0.00	0.00	0.00	0.00	1.42	2.19	33.33
muh rac	0.00	0.00	0.00	0.71	1.73	16.67	2.12	5.20	16.67
nas vir	16.99	39.56	33.33	0.00	0.00	0.00	0.00	0.00	0.00
pas smi	0.00	0.00	0.00	0.71	1.73	16.67	23.35	30.00	66.67
poa ann	0.00	0.00	0.00	0.00	0.00	0.00	2.12	5.20	16.67
poa pra	76.43	76.72	100.00	38.22	29.78	83.33	24.77	31.60	66.67
pol con	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
rat col	0.00	0.00	0.00	1.42	3.47	16.67	0.00	0.00	0.00
tar off	10.62	17.97	66.67	6.37	7.94	66.67	2.83	6.93	16.67
thl arv	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
tra dub	0.71	1.73	16.67	1.42	3.47	16.67	2.12	3.55	33.33
vul oct	0.71	1.73	16.67	1.42	2.19	33.33	0.00	0.00	0.00

Silver Sage Vegetation Association

Species	Persistent								
	-----Non-infested-----			-----Infested-----			-----Bio-control-----		
	mean	std	freq	mean	std	freq	mean	std	freq
ach mil	7.08	11.29	33.33	0.00	0.00	0.00	2.83	6.93	16.67
ama alb	0.71	1.73	16.67	0.00	0.00	0.00	1.42	3.47	16.67
amb psi	1.42	3.47	16.67	0.00	0.00	0.00	0.00	0.00	0.00
and ger	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
and occ	0.71	1.73	16.67	6.37	11.94	33.33	0.00	0.00	0.00
Arabis spp.	2.12	3.55	33.33	0.00	0.00	0.00	0.71	1.73	16.67
art fri	2.83	4.39	33.33	21.23	49.95	33.33	0.00	0.00	0.00
art lud	2.83	5.14	33.33	26.19	32.16	66.67	3.54	6.80	33.33
ast eri	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
ast lea	0.00	0.00	0.00	3.54	6.80	33.33	0.00	0.00	0.00
bro ine	2.83	5.14	33.33	28.31	59.31	50.00	0.00	0.00	0.00
bro jap	24.77	56.55	50.00	104.74	246.31	33.33	0.00	0.00	0.00
cal lon	0.00	0.00	0.00	1.42	3.47	16.67	0.00	0.00	0.00
cam mic	1.42	3.47	16.67	0.00	0.00	0.00	0.00	0.00	0.00
car bre	0.00	0.00	0.00	2.83	6.93	16.67	0.00	0.00	0.00
cer arv	12.74	31.20	16.67	27.60	49.14	50.00	0.00	0.00	0.00
che lep	2.12	3.55	33.33	1.42	3.47	16.67	0.00	0.00	0.00
col lin	0.71	1.73	16.67	5.66	13.87	16.67	1.42	2.19	33.33

Table A-6 continued

con can	12.03	16.21	50.00	4.95	3.20	83.33	0.71	1.73	16.67
dau car	0.00	0.00	0.00	2.83	3.47	50.00	0.00	0.00	0.00
des sop	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
eri can	2.83	6.93	16.67	0.00	0.00	0.00	0.71	1.73	16.67
eri str	0.00	0.00	0.00	0.00	0.00	0.00	2.12	3.55	33.33
ery asp	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
eup eus	6.37	15.60	16.67	505.31	536.88	100.00	339.00	431.57	83.33
eup spa	51.66	56.04	83.33	34.68	70.77	50.00	89.88	119.36	66.67
gal bor	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
hed his	25.48	25.76	66.67	31.85	30.12	66.67	7.78	9.46	50.00
hes com	0.71	1.73	16.67	1.42	3.47	16.67	0.00	0.00	0.00
jun tor	0.00	0.00	0.00	1.42	3.47	16.67	0.00	0.00	0.00
koe mac	0.00	0.00	0.00	9.20	18.69	33.33	0.00	0.00	0.00
lac obl	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
lac ser	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
les arn	2.83	5.14	33.33	6.37	10.66	33.33	0.00	0.00	0.00
lin per	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
lin rig	0.71	1.73	16.67	0.00	0.00	0.00	0.71	1.73	16.67
lot pur	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
mel off	2.83	5.14	33.33	4.95	8.67	33.33	3.54	8.67	16.67
muh rac	0.00	0.00	0.00	3.54	5.64	33.33	4.95	10.20	33.33
nas vir	9.91	22.25	33.33	0.00	0.00	0.00	0.71	1.73	16.67
pas smi	0.00	0.00	0.00	5.66	13.87	16.67	1.42	2.19	33.33
poa ann	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
poa can	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
poa pra	18.40	43.03	33.33	20.52	27.05	66.67	2.83	3.47	50.00
pol con	1.42	3.47	16.67	0.71	1.73	16.67	0.00	0.00	0.00
rat col	0.00	0.00	0.00	0.71	1.73	16.67	0.71	1.73	16.67
sol mis	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
sol rig	0.00	0.00	0.00	0.71	1.73	16.67	1.42	3.47	16.67
sol tri	7.08	17.34	16.67	9.91	24.27	16.67	0.00	0.00	0.00
spo cry	1.42	3.47	16.67	0.00	0.00	0.00	0.71	1.73	16.67
tar off	0.71	1.73	16.67	0.71	1.73	16.67	0.71	1.73	16.67
tra dub	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
ver bra	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
vul oct	0.00	0.00	0.00	4.25	7.11	33.33	0.71	1.73	16.67
ver bra	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.28	16.67
vul oct	0.00	0.00	0.00	4.25	7.11	33.33	0.71	9.83	16.67

Silver Sage Vegetation Association

Species	Dormant								
	-----Non-infested-----			-----Infested-----			-----Bio-control-----		
	mean	std	freq	mean	std	freq	mean	std	freq
ama alb	4.95	12.13	16.67	1.42	2.19	33.33	1.42	3.47	16.67
amb psi	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
amo can	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
and occ	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
ara spp	1.42	3.47	16.67	0.00	0.00	0.00	0.00	0.00	0.00
art fri	2.12	5.20	16.67	2.12	3.55	33.33	0.71	1.73	16.67

Table A-6 continued

art spp	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
cam mic	12.03	29.47	16.67	0.00	0.00	0.00	24.06	58.94	16.67
car gra	0.00	0.00	0.00	5.66	13.87	16.67	0.00	0.00	0.00
car sp#10	0.00	0.00	0.00	0.00	0.00	0.00	1.42	3.47	16.67
car sp#3	0.00	0.00	0.00	1.42	3.47	16.67	4.25	10.40	16.67
che spp	111.82	165.43	66.67	82.09	116.25	100.00	172.68	170.97	83.33
col lin	4.95	6.80	50.00	1.42	3.47	16.67	0.71	1.73	16.67
dal pur	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
des pin	33.26	43.67	66.67	13.45	13.27	66.67	35.39	41.05	66.67
des sop	8.49	16.77	50.00	5.66	9.17	33.33	19.82	25.57	50.00
ell nyc	2.12	3.55	33.33	15.57	36.10	33.33	0.00	0.00	0.00
ery asp	0.00	0.00	0.00	0.00	0.00	0.00	1.42	2.19	33.33
eup eus	0.00	0.00	0.00	7.78	15.05	50.00	4.25	6.58	50.00
eup gly	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
eup spa	21.23	21.98	66.67	2.12	3.55	33.33	33.26	38.86	83.33
fabaceae3	0.00	0.00	0.00	7.08	17.34	16.67	0.71	1.73	16.67
fabaceae1	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
gal spp	1.42	3.47	16.67	0.00	0.00	0.00	2.12	5.20	16.67
hed his	4.95	6.25	50.00	2.83	5.14	33.33	9.91	11.60	50.00
hel spp	2.12	5.20	16.67	0.00	0.00	0.00	0.00	0.00	0.00
hes com	7.08	8.35	50.00	5.66	3.47	83.33	4.95	10.20	33.33
hyo nig	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
lac obl	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
lap occ	6.37	8.39	50.00	0.00	0.00	0.00	0.00	0.00	0.00
lep den	6.37	13.63	33.33	3.54	6.80	33.33	4.25	10.40	16.67
les arm	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
lin lew	38.22	93.61	16.67	0.00	0.00	0.00	0.71	1.73	16.67
lin rig	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
lit inc	1.42	3.47	16.67	1.42	3.47	16.67	0.00	0.00	0.00
lot pur	18.40	45.07	16.67	0.00	0.00	0.00	0.00	0.00	0.00
mel off	928.52	1753.12	83.33	500.35	257.36	100.00	932.77	1235.30	83.33
mon fis	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
nas vir	4.25	6.58	50.00	2.12	5.20	16.67	2.83	3.47	50.00
oen spp	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
par pen	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
pla elo	2.12	3.55	33.33	0.00	0.00	0.00	0.00	0.00	0.00
pla maj	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
poa pra	6.37	7.48	50.00	4.25	3.80	66.67	1.42	3.47	16.67
pol con	4.25	5.37	50.00	7.78	17.07	33.33	0.00	0.00	0.00
scirpl	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
scr sp#4	0.00	0.00	0.00	3.54	8.67	16.67	0.00	0.00	0.00
sol tri	0.71	1.73	16.67	0.71	1.73	16.67	0.00	0.00	0.00
sph coc	14.15	16.91	50.00	0.00	0.00	0.00	0.00	0.00	0.00
spo cry	7.08	8.35	66.67	10.62	20.05	50.00	14.15	25.15	50.00
sym occ	0.71	1.73	16.67	0.71	1.73	16.67	0.71	1.73	16.67
thl arv	12.03	29.47	16.67	0.00	0.00	0.00	0.00	0.00	0.00
unk pear	0.00	0.00	0.00	1.42	2.19	33.33	2.83	4.39	33.33
unk spp	0.00	0.00	0.00	0.71	1.73	16.67	3.54	5.64	33.33
vic ame	2.12	5.20	16.67	0.71	1.73	16.67	0.71	1.73	16.67

Table A-6 continued

Green Ash Draw Vegetation Association									
Early Transient Seed Bank									
Species	-----Non-infested-----			-----Infested-----			-----Bio-control-----		
	mean	std	freq	mean	std	freq	mean	std	freq
amb tri	0.85	1.90	16.67	0.00	0.00	0.00	0.00	0.00	0.00
arc min	3.40	5.54	33.33	0.00	0.00	0.00	5.66	10.29	33.33
art fri	0.00	0.00	0.00	2.12	2.45	33.33	2.83	6.93	16.67
ast lea	0.85	1.90	16.67	0.00	0.00	0.00	0.00	0.00	0.00
bro ine	0.00	0.00	0.00	3.18	6.37	16.67	0.00	0.00	0.00
bro jap	62.85	140.53	16.67	0.00	0.00	0.00	0.00	0.00	0.00
carex sp	0.00	0.00	0.00	2.12	4.25	16.67	2.83	4.39	33.33
des sop	0.85	1.90	16.67	0.00	0.00	0.00	0.00	0.00	0.00
cly vir	4.25	7.35	33.33	0.00	0.00	0.00	4.25	6.58	33.33
eri str	1.70	3.80	16.67	0.00	0.00	0.00	0.00	0.00	0.00
eup eus	18.68	32.70	50.00	20.17	40.34	16.67	0.00	0.00	0.00
fra pen	3.40	5.54	33.33	2.12	4.25	16.67	9.20	12.13	50.00
fra ves	1.70	3.80	16.67	0.00	0.00	0.00	0.00	0.00	0.00
gal apr	5.94	11.07	33.33	0.00	0.00	0.00	1.42	3.47	16.67
gal bor	0.85	1.90	16.67	0.00	0.00	0.00	1.42	2.19	33.33
koe mac	1.70	3.80	16.67	0.00	0.00	0.00	0.00	0.00	0.00
lac obl	0.00	0.00	0.00	1.06	2.12	16.67	0.00	0.00	0.00
lac ser	0.00	0.00	0.00	0.00	0.00	0.00	9.20	12.13	50.00
lap squ	7.64	11.39	33.33	0.00	0.00	0.00	8.49	10.74	50.00
mon fis	0.85	1.90	16.67	0.00	0.00	0.00	2.83	5.14	33.33
muh rac	0.00	0.00	0.00	5.31	6.37	33.33	1.42	3.47	16.67
pas smi	0.85	1.90	16.67	0.00	0.00	0.00	2.12	5.20	16.67
pip mic	2.55	5.70	16.67	0.00	0.00	0.00	0.00	0.00	0.00
poa ann	0.00	0.00	0.00	4.25	8.49	16.67	27.60	49.36	66.67
poa pra	5.10	4.65	50.00	4.25	8.49	16.67	2.83	4.39	33.33
ran abo	3.40	4.65	33.33	6.37	12.74	16.67	2.83	6.93	16.67
ran abo	3.40	4.65	33.33	6.37	12.74	16.67	2.83	6.93	16.67
set ver	0.85	1.90	16.67	0.00	0.00	0.00	0.00	0.00	0.00
tar off	16.14	13.22	83.33	4.25	8.49	16.67	4.95	4.17	66.67
tha das	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
tra dub	0.00	0.00	0.00	0.00	0.00	0.00	1.42	2.19	33.33

Green Ash Draw Vegetation Association									
Late Transient Seed Bank									
Species	-----Non-infested-----			-----Infested-----			-----Bio-control-----		
	mean	std	freq	mean	std	freq	mean	std	freq
ama alb	15.57	17.95	50.00	5.31	8.04	33.33	9.91	18.35	50.00
and occ	0.00	0.00	0.00	0.00	0.00	0.00	2.12	5.20	16.67
Arabis	0.00	0.00	0.00	0.00	0.00	0.00	2.12	5.20	16.67
arc min	17.69	33.26	66.67	0.00	0.00	0.00	16.99	33.97	33.33
bro ine	1.42	3.47	16.67	0.00	0.00	0.00	35.39	86.68	16.67
bro jap	0.00	0.00	0.00	0.00	0.00	0.00	12.74	31.20	16.67

Table A-6 continued

car int	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
carex sp	1.42	3.47	16.67	0.00	0.00	0.00	2.83	6.93	16.67
che fre	4.95	10.20	33.33	0.00	0.00	0.00	0.00	0.00	0.00
che lep	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
con can	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
des sop	0.00	0.00	0.00	1.06	2.12	16.67	0.00	0.00	0.00
ely tra	2.12	3.55	33.33	66.88	130.94	33.33	7.08	11.29	33.33
ely vir	22.65	51.43	33.33	9.55	12.20	33.33	1.42	3.47	16.67
eri str	1.42	2.19	33.33	1.06	2.12	16.67	0.71	1.73	16.67
eup eus	0.71	1.73	16.67	131.63	129.77	66.67	16.28	25.25	50.00
eup spa	0.00	0.00	0.00	0.00	0.00	0.00	1.42	2.19	33.33
fra pen	68.65	99.56	100.00	110.40	176.79	50.00	11.32	19.67	66.67
fra ves	9.20	18.69	33.33	0.00	0.00	0.00	2.12	5.20	16.67
fra vir	2.83	6.93	16.67	0.00	0.00	0.00	0.00	0.00	0.00
gal apr	19.11	19.87	83.33	2.12	4.25	16.67	4.95	8.24	50.00
gal bor	9.91	17.34	33.33	8.49	16.99	16.67	32.55	36.89	66.67
heu ric	9.20	15.76	33.33	0.00	0.00	0.00	1.42	3.47	16.67
koe mac	1.42	3.47	16.67	0.00	0.00	0.00	0.00	0.00	0.00
lac obl	5.66	10.29	33.33	19.11	24.39	66.67	5.66	7.44	50.00
lac ser	2.12	5.20	16.67	0.00	0.00	0.00	1.42	2.19	33.33
lap occ	2.83	6.93	16.67	0.00	0.00	0.00	0.00	0.00	0.00
lin per	0.00	0.00	0.00	0.00	0.00	0.00	1.42	2.19	33.33
lot pur	0.00	0.00	0.00	1.06	2.12	16.67	0.00	0.00	0.00
lys cil	2.83	6.93	16.67	1.06	2.12	16.67	0.00	0.00	0.00
mon fis	0.00	0.00	0.00	2.12	4.25	16.67	7.78	9.46	50.00
muh rac	0.00	0.00	0.00	2.12	4.25	16.67	2.83	3.47	50.00
muh spp	1.42	3.47	16.67	0.00	0.00	0.00	0.00	0.00	0.00
pas smi	4.95	7.79	33.33	0.00	0.00	0.00	4.95	10.20	33.33
pip mic	2.83	6.93	16.67	2.12	4.25	16.67	0.00	0.00	0.00
poa ann	0.71	1.73	16.67	2.12	4.25	16.67	0.00	0.00	0.00
poa com	0.00	0.00	0.00	4.25	8.49	16.67	0.00	0.00	0.00
poa pra	16.28	17.90	50.00	11.68	16.03	33.33	30.43	26.91	83.33
pol con	8.49	13.43	33.33	0.00	0.00	0.00	0.71	1.73	16.67
ran abo	0.00	0.00	0.00	1.06	2.12	16.67	15.57	36.10	33.33
ran abo	0.00	0.00	0.00	1.06	2.12	16.67	15.57	36.10	33.33
rib aur	5.66	11.91	33.33	0.00	0.00	0.00	5.66	13.87	16.67
sal ibe	2.12	5.20	16.67	0.00	0.00	0.00	0.00	0.00	0.00
she arg	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
sol mol	0.00	0.00	0.00	0.00	0.00	0.00	3.54	8.67	16.67
sol spp	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
tar off	10.62	15.83	50.00	0.00	0.00	0.00	4.25	5.37	50.00
tha das	1.42	3.47	16.67	0.00	0.00	0.00	1.42	3.47	16.67
tox ryd	0.00	0.00	0.00	1.06	2.12	16.67	0.00	0.00	0.00
tra dub	0.00	0.00	0.00	2.12	4.25	16.67	2.83	3.47	50.00
urt dio	0.71	1.73	16.67	0.00	0.00	0.00	4.25	10.40	16.67
vul oct	0.00	0.00	0.00	0.00	0.00	0.00	11.32	27.74	16.67

Table A-6 continued

Green Ash Draw Vegetation Association									
Early and Late Transient Seed Banks									
Species	-----Non-infested-----			-----Infested-----			-----Bio-control-----		
	mean	std	freq	mean	std	freq	mean	std	freq
ama alb	15.57	17.95	50.00	7.08	8.84	50.00	9.91	18.35	50.00
amb tri	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
and occ	0.00	0.00	0.00	0.00	0.00	0.00	2.12	5.20	16.67
arabis sp	0.00	0.00	0.00	0.00	0.00	0.00	2.12	5.20	16.67
arc min	20.52	34.01	83.33	0.00	0.00	0.00	22.65	36.30	50.00
art fri	0.00	0.00	0.00	2.83	2.45	50.00	2.83	6.93	16.67
ast lea	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
bro ine	1.42	3.47	16.67	4.25	7.35	25.00	35.39	86.68	16.67
bro jap	52.37	128.28	16.67	0.00	0.00	0.00	12.74	31.20	16.67
car int	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
carex sp	1.42	3.47	16.67	0.00	0.00	0.00	5.66	10.29	33.33
che fre	4.95	10.20	33.33	0.00	0.00	0.00	0.00	0.00	0.00
che lep	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
con can	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
des sop	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
ely tra	2.12	3.55	33.33	89.17	150.79	50.00	7.08	11.29	33.33
ely vir	26.19	49.98	66.67	8.49	14.71	25.00	5.66	6.39	50.00
eri str	2.83	3.47	50.00	1.42	2.45	25.00	0.71	1.73	16.67
eup eus	16.28	29.96	50.00	179.76	195.16	75.00	16.28	25.25	50.00
eup spa	0.00	0.00	0.00	0.00	0.00	0.00	1.42	2.19	33.33
fra pen	71.48	100.18	100.00	144.37	207.50	50.00	20.52	30.08	83.33
fra ves	10.62	22.11	33.33	0.00	0.00	0.00	2.12	5.20	16.67
fra vir	2.83	6.93	16.67	0.00	0.00	0.00	0.00	0.00	0.00
gal apr	24.06	20.22	83.33	2.83	4.90	25.00	6.37	11.63	50.00
gal bor	10.62	16.93	50.00	11.32	19.61	25.00	33.97	39.01	66.67
heu ric	9.20	15.76	33.33	0.00	0.00	0.00	1.42	3.47	16.67
koe mac	2.83	6.93	16.67	0.00	0.00	0.00	0.00	0.00	0.00
lac obl	5.66	10.29	33.33	22.65	28.27	75.00	5.66	7.44	50.00
lac ser	2.12	5.20	16.67	0.00	0.00	0.00	10.62	10.99	83.33
lap occ	2.83	6.93	16.67	0.00	0.00	0.00	0.00	0.00	0.00
lot pur	0.00	0.00	0.00	1.42	2.45	25.00	0.00	0.00	0.00
lap squ	6.37	10.66	33.33	0.00	0.00	0.00	8.49	10.74	50.00
lin per	0.00	0.00	0.00	0.00	0.00	0.00	1.42	2.19	33.33
lys cil	2.83	6.93	16.67	0.00	0.00	0.00	0.00	0.00	0.00
mon fis	0.71	1.73	16.67	2.83	4.90	25.00	10.62	14.15	50.00
muh spp	1.42	3.47	16.67	9.91	8.84	50.00	4.25	3.80	66.67
pas smi	5.66	9.17	33.33	0.00	0.00	0.00	7.08	15.35	33.33
pip mic	4.95	7.79	33.33	2.83	4.90	25.00	0.00	0.00	0.00
poa ann	0.71	1.73	16.67	2.83	4.90	25.00	27.60	49.36	66.67
poa com	0.00	0.00	0.00	5.66	9.81	25.00	0.00	0.00	0.00
poa pra	20.52	13.27	100.00	21.23	18.51	50.00	33.26	24.67	100.00
pol con	8.49	13.43	33.33	0.00	0.00	0.00	0.71	1.73	16.67
ran abo	2.83	4.39	33.33	9.91	17.16	25.00	18.40	43.03	33.33
rib aur	5.66	11.91	33.33	0.00	0.00	0.00	5.66	13.87	16.67

Table A-6 continued

sal ibe	2.12	5.20	16.67	0.00	0.00	0.00	0.00	0.00	0.00
set ver	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
she arg	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
sol spp	0.71	1.73	16.67	0.00	0.00	25.00	3.54	8.67	16.67
tar off	24.06	18.15	100.00	5.66	9.81	0.00	9.20	7.31	83.33
tha das	1.42	3.47	16.67	0.00	0.00	25.00	2.12	3.55	33.33
tra dub	0.00	0.00	0.00	2.83	4.90	25.00	4.25	4.65	50.00
tox ryd	0.00	0.00	0.00	1.42	2.45	0.00	0.00	0.00	0.00
urt dio	0.71	1.73	16.67	0.00	0.00	0.00	4.25	10.40	16.67
vul oct	0.00	0.00	0.00	0.00	0.00	0.00	11.32	27.74	16.67

Green Ash Draw Vegetation Association

Species	Persistent Seed Bank								
	-----Non-infested-----			-----Infested-----			-----Bio-control-----		
	mean	std	freq	mean	std	freq	mean	std	freq
ama alb	36.09	62.51	50.00	1.06	2.12	16.67	12.03	12.43	66.67
and occ	0.00	0.00	0.00	0.00	0.00	0.00	16.99	27.52	33.33
arabis	2.12	5.20	16.67	0.00	0.00	0.00	12.03	19.81	33.33
arc min	82.80	145.04	83.33	3.18	6.37	16.67	11.32	18.54	50.00
art fri	0.00	0.00	0.00	1.06	2.12	16.67	0.00	0.00	0.00
ast lea	4.25	10.40	16.67	0.00	0.00	0.00	0.00	0.00	0.00
car bre	15.57	34.15	33.33	0.00	0.00	0.00	9.91	12.21	50.00
car gra	2.12	5.20	16.67	0.00	0.00	0.00	0.00	0.00	0.00
car ped	7.78	10.20	50.00	0.00	0.00	0.00	0.00	0.00	0.00
cer arv	0.00	0.00	0.00	0.00	0.00	0.00	13.45	25.54	33.33
cer spp	0.71	1.73	16.67	2.12	4.25	16.67	0.00	0.00	0.00
che fre	4.95	8.24	50.00	0.00	0.00	0.00	2.12	3.55	33.33
che gig	7.08	10.29	50.00	0.00	0.00	0.00	1.42	3.47	16.67
che lep	0.71	1.73	16.67	2.12	4.25	16.67	6.37	9.96	50.00
con can	3.54	6.80	33.33	0.00	0.00	0.00	2.83	3.47	50.00
des sop	1.42	3.47	16.67	0.00	0.00	0.00	0.00	0.00	0.00
ely vir	0.00	0.00	0.00	8.49	16.99	16.67	5.66	13.87	16.67
eri fla	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
eri str	0.00	0.00	0.00	1.06	2.12	16.67	2.12	5.20	16.67
ery asp	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
eup eus	1.42	2.19	33.33	1070.06	960.19	66.67	290.16	435.12	83.33
eup spa	4.25	7.11	33.33	19.11	35.44	33.33	5.66	11.91	33.33
fra pen	0.71	1.73	16.67	14.86	19.15	50.00	2.83	5.14	33.33
fra ves	2.83	5.14	33.33	0.00	0.00	0.00	4.95	10.20	33.33
gal apr	53.08	63.71	83.33	5.31	10.62	16.67	9.20	13.00	66.67
gal bor	7.08	17.34	16.67	0.00	0.00	0.00	5.66	8.35	50.00
geu tri	0.00	0.00	0.00	0.00	0.00	0.00	2.12	5.20	16.67
hed his	1.42	3.47	16.67	49.89	99.79	16.67	0.00	0.00	0.00
heu ric	2.12	2.33	50.00	0.00	0.00	0.00	1.42	3.47	16.67
koe mac	0.71	1.73	16.67	1.06	2.12	16.67	0.00	0.00	0.00
lac ser	5.66	5.80	66.67	3.18	6.37	16.67	6.37	6.44	66.67
lin per	0.00	0.00	0.00	0.00	0.00	0.00	1.42	3.47	16.67
lot pur	0.00	0.00	0.00	7.43	8.75	33.33	0.00	0.00	0.00
lys cil	12.74	17.40	66.67	19.11	38.22	16.67	9.20	22.54	16.67

Table A-6 continued

mel off	1.42	3.47	16.67	0.00	0.00	0.00	2.12	5.20	16.67
mon fis	0.00	0.00	0.00	0.00	0.00	0.00	17.69	35.26	50.00
muh rac	2.12	5.20	16.67	0.00	0.00	0.00	2.12	3.55	33.33
nas vir	63.69	151.90	33.33	0.00	0.00	0.00	0.00	0.00	0.00
pan cap	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
pas smi	2.12	5.20	16.67	3.18	6.37	16.67	3.54	6.80	33.33
pip mic	125.27	300.61	50.00	0.00	0.00	0.00	1.42	3.47	16.67
pla maj	1.42	3.47	16.67	0.00	0.00	0.00	1.42	2.19	33.33
poa ann	4.25	10.40	16.67	0.00	0.00	0.00	0.00	0.00	0.00
poa com	12.03	25.54	33.33	46.71	82.48	33.33	3.54	4.96	50.00
poa pra	18.40	35.08	50.00	6.37	12.74	16.67	354.56	671.66	83.33
pol con	1.42	2.19	33.33	0.00	0.00	0.00	0.71	1.73	16.67
pol dou	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
pot arg	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
pso agr	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
ran abo	4.25	10.40	16.67	1.06	2.12	16.67	23.35	41.76	50.00
ran abo	4.25	10.40	16.67	1.06	2.12	16.67	23.35	41.76	50.00
rat col	0.71	1.73	16.67	2.12	4.25	16.67	2.83	6.93	16.67
rib aur	0.00	0.00	0.00	0.00	0.00	0.00	3.54	6.80	33.33
sol rig	0.71	1.73	16.67	5.31	10.62	16.67	0.00	0.00	0.00
sol tri	2.83	5.14	33.33	0.00	0.00	0.00	12.74	31.20	16.67
tar off	2.83	6.93	16.67	3.18	6.37	16.67	9.91	11.60	66.67
tha das	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
tra dub	0.00	0.00	0.00	1.06	2.12	16.67	0.00	0.00	0.00
vul oct	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00

Green Ash Draw Vegetation Association

Species	Dormant Seed Bank								
	-----Non-infested-----			-----Infested-----			-----Bio-control-----		
	mean	std	freq	mean	std	freq	mean	std	freq
ama alb	11.32	21.60	66.67	19.11	38.22	16.67	4.95	8.24	50.00
ara spp	0.71	1.73	16.67	0.00	0.00	0.00	0.71	1.73	16.67
arc min	1.42	3.47	16.67	0.00	0.00	0.00	0.00	0.00	0.00
art fri	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
art lud	0.71	1.73	16.67	0.00	0.00	0.00	0.71	1.73	16.67
astr spp	0.00	0.00	0.00	13.80	18.14	33.33	0.00	0.00	0.00
cam mic	1.42	2.19	33.33	0.00	0.00	0.00	0.00	0.00	0.00
car gra	0.71	1.73	16.67	0.00	0.00	0.00	0.71	1.73	16.67
car sp#1	2.83	6.93	16.67	0.00	0.00	0.00	55.91	107.57	50.00
car sp#10	2.83	6.93	16.67	0.00	0.00	0.00	7.78	12.13	33.33
car sp#3	0.71	1.73	16.67	0.00	0.00	0.00	5.66	13.87	16.67
car spr	4.95	12.13	16.67	0.00	0.00	0.00	0.00	0.00	0.00
cer spp	0.00	0.00	0.00	2.12	4.25	16.67	1.42	3.47	16.67
che gig	65.82	84.83	50.00	0.00	0.00	0.00	2.12	5.20	16.67
che spp	160.65	297.40	100.00	31.85	29.72	50.00	78.56	79.79	100.00
dal pur	0.71	1.73	16.67	18.05	36.09	16.67	0.71	1.73	16.67
des pin	2.83	3.47	50.00	2.12	2.45	33.33	0.00	0.00	0.00
des sop	12.74	27.26	33.33	0.00	0.00	0.00	2.12	5.20	16.67
ell nyc	17.69	32.50	33.33	1.06	2.12	16.67	27.60	45.71	66.67

ery asp	0.00	0.00	0.00	0.00	0.00	0.00	1.42	3.47	16.67
ery che	10.62	26.00	16.67	0.00	0.00	0.00	2.83	6.93	16.67
eup eus	0.00	0.00	0.00	2.12	2.45	33.33	3.54	8.67	16.67
eup spa	0.00	0.00	0.00	1.06	2.12	16.67	0.71	1.73	16.67
fra pen	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
fra ves	0.71	1.73	16.67	0.00	0.00	0.00	3.54	8.67	16.67
gal apr	1.42	3.47	16.67	0.00	0.00	0.00	9.91	24.27	16.67
gal bor	2.83	6.93	16.67	4.25	6.01	33.33	7.78	17.07	33.33
gal spp	33.97	54.31	50.00	0.00	0.00	0.00	10.62	18.36	50.00
hed his	0.00	0.00	0.00	1.06	2.12	16.67	0.71	1.73	16.67
hes com	0.00	0.00	0.00	2.12	4.25	16.67	1.42	3.47	16.67
hes spa	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
lep den	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
lin lew	0.00	0.00	0.00	1.06	2.12	16.67	4.95	8.24	50.00
mel off	16.28	23.01	83.33	134.82	173.71	66.67	58.74	90.13	100.00
mon fis	0.00	0.00	0.00	0.00	0.00	0.00	2.83	5.14	33.33
nas vir	0.71	1.73	16.67	4.25	8.49	16.67	7.78	19.07	16.67
pap dub	0.00	0.00	0.00	1.06	2.12	16.67	0.00	0.00	0.00
par pen	43.88	58.88	50.00	4.25	8.49	16.67	12.74	8.91	83.33
pip mic	57.32	102.40	50.00	0.00	0.00	0.00	1.42	2.19	33.33
poa com	0.00	0.00	0.00	0.00	0.00	0.00	2.83	6.93	16.67
poa pra	0.00	0.00	0.00	4.25	8.49	16.67	2.12	3.55	33.33
pol alb	0.71	1.73	16.67	0.00	0.00	0.00	2.83	6.93	16.67
pol con	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
pol dou	0.00	0.00	0.00	1.06	2.12	16.67	0.00	0.00	0.00
pol ere	1.42	3.47	16.67	0.00	0.00	0.00	0.00	0.00	0.00
pot pen	24.77	60.67	16.67	0.00	0.00	0.00	2.12	3.55	33.33
pso agr	0.00	0.00	0.00	38.22	76.43	16.67	0.00	0.00	0.00
ran abo	0.71	1.73	16.67	10.62	21.23	16.67	8.49	16.99	33.33
ran abo	0.71	1.73	16.67	10.62	21.23	16.67	8.49	16.99	33.33
scr sp#4	0.00	0.00	0.00	0.00	0.00	0.00	1.42	3.47	16.67
sil ant	8.49	20.80	16.67	0.00	0.00	0.00	0.00	0.00	0.00
sol tri	2.12	3.55	33.33	0.00	0.00	0.00	0.00	0.00	0.00
sph coc	1.42	2.19	33.33	4.25	8.49	16.67	7.08	8.35	66.67
spo cry	0.00	0.00	0.00	4.25	6.01	33.33	0.71	1.73	16.67
sym occ	0.00	0.00	0.00	1.06	2.12	16.67	0.00	0.00	0.00
unk pear	9.20	6.25	83.33	3.18	6.37	16.67	24.77	42.16	33.33
unk spp	5.66	9.17	33.33	5.31	8.04	33.33	9.20	4.96	83.33
unk spp	2.83	3.47	50.00	1.06	2.12	16.67	3.54	1.73	83.33
vic ame	0.00	0.00	0.00	1.06	2.12	16.67	0.00	0.00	0.00
viola spp	0.71	1.73	16.67	0.00	0.00	0.00	1.42	2.19	33.33

Table A-6 continued

Needle-and-thread Vegetation Association									
Late Transient Seed Bank									
Species	-----Non-infested-----			-----Infested-----			-----Bio-control-----		
	mean	std	freq	mean	std	freq	mean	std	freq
and occ	0.00	0.00	0.00	0.00	0.00	0.00	4.25	8.49	33.33
ant par	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
Arabis	2.12	4.25	16.67	0.00	0.00	0.00	0.71	1.73	16.67
arc min	3.18	6.37	16.67	0.00	0.00	0.00	18.40	45.07	16.67
art dra	2.12	4.25	16.67	0.00	0.00	0.00	0.00	0.00	0.00
art fri	1.06	2.12	16.67	4.25	3.47	50.00	6.37	13.63	33.33
art lud	1.06	2.12	16.67	1.06	2.12	16.67	1.42	2.19	33.33
bro ine	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
bro jap	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
cha mac	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
con can	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
des sop	0.00	0.00	0.00	2.12	4.25	16.67	0.00	0.00	0.00
ery asp	0.00	0.00	0.00	3.18	6.37	16.67	0.00	0.00	0.00
eup eus	0.00	0.00	0.00	23.35	38.69	33.33	3.54	5.64	33.33
eup spa	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
fra pen	3.18	6.37	16.67	3.18	6.37	16.67	2.83	6.93	16.67
hed his	3.18	6.37	16.67	1.06	2.12	16.67	2.83	3.47	50.00
lac ser	3.18	6.37	16.67	8.49	12.01	33.33	0.00	0.00	0.00
mel off	1.06	2.12	16.67	0.00	0.00	0.00	0.00	0.00	0.00
nas vir	1.06	2.12	16.67	2.12	4.25	16.67	0.71	1.73	16.67
pas smi	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
poa pra	0.00	0.00	0.00	1.06	2.12	16.67	2.83	6.93	16.67
sta pin	1.06	2.12	16.67	0.00	0.00	0.00	0.00	0.00	0.00
tar off	7.43	9.42	50.00	10.62	12.74	33.33	9.91	14.38	66.67
tra dub	5.31	8.04	33.33	4.25	3.47	50.00	0.71	1.73	16.67
unk brassica	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67

Needle-and-thread Vegetation Association									
Early Transient Seed Banks									
Species	-----Non-infested-----			-----Infested-----			-----Bio-control-----		
	mean	std	freq	mean	std	freq	mean	std	freq
and ger	0.00	0.00	0.00	2.83	4.39	33.33	5.66	13.87	16.67
and occ	0.00	0.00	0.00	0.00	0.00	0.00	2.83	5.14	33.33
ant neg	1.42	3.47	16.67	0.00	0.00	0.00	0.00	0.00	0.00
Arabis	0.00	0.00	0.00	2.12	3.55	33.33	0.00	0.00	0.00
arc min	0.00	0.00	0.00	0.00	0.00	0.00	1.42	3.47	16.67
art dra	2.12	5.20	16.67	0.00	0.00	0.00	0.00	0.00	0.00
art fri	0.71	1.73	16.67	19.82	20.74	66.67	6.37	6.98	66.67
bou cur	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
bro ine	0.00	0.00	0.00	0.71	1.73	16.67	0.71	1.73	16.67
bro jap	0.00	0.00	0.00	2.83	5.14	33.33	0.71	1.73	16.67
cal lon	2.12	5.20	16.67	0.00	0.00	0.00	0.00	0.00	0.00
car fil	0.71	1.73	16.67	2.12	3.55	33.33	2.83	4.39	33.33

Table A-6 continued

carex sp	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
con can	0.00	0.00	0.00	7.78	7.79	66.67	2.83	3.47	50.00
dal pur	0.00	0.00	0.00	0.71	1.73	16.67	0.71	1.73	16.67
des sop	0.00	0.00	0.00	2.83	6.93	16.67	0.00	0.00	0.00
eri fla	1.42	3.47	16.67	5.66	10.29	33.33	0.00	0.00	0.00
eri pau	0.00	0.00	0.00	13.45	20.17	50.00	0.71	1.73	16.67
eup eus	0.00	0.00	0.00	113.94	109.00	66.67	12.03	12.72	66.67
eup spa	1.42	3.47	16.67	0.00	0.00	0.00	0.00	0.00	0.00
fra pen	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
fra vir	2.12	5.20	16.67	0.00	0.00	0.00	0.00	0.00	0.00
gal apr	0.71	1.73	16.67	0.00	0.00	0.00	1.42	3.47	16.67
hed his	2.12	3.55	33.33	33.26	42.33	66.67	2.12	3.55	33.33
hes com	4.95	12.13	16.67	2.12	3.55	33.33	9.91	9.93	66.67
koe mac	2.83	4.39	33.33	4.25	8.49	33.33	5.66	5.14	66.67
lac obl	0.00	0.00	0.00	0.71	1.73	16.67	0.71	1.73	16.67
lac ser	1.42	3.47	16.67	9.20	12.13	50.00	5.66	6.39	50.00
lep lat	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
lin per	1.42	3.47	16.67	0.00	0.00	0.00	0.00	0.00	0.00
lin rig	0.00	0.00	0.00	1.42	3.47	16.67	1.42	2.19	33.33
mon fis	0.00	0.00	0.00	0.00	0.00	0.00	2.12	5.20	16.67
muh rac	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
nas vir	5.66	6.39	50.00	0.71	1.73	16.67	2.12	3.55	33.33
pas smi	0.71	1.73	16.67	1.42	2.19	33.33	0.00	0.00	0.00
poa pra	2.83	6.93	16.67	2.83	6.93	16.67	23.35	38.71	50.00
rat col	4.95	6.80	50.00	1.42	3.47	16.67	0.71	1.73	16.67
tar off	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
thl arv	0.71	1.73	16.67	2.12	3.55	33.33	1.42	2.19	33.33
tra bra	0.00	0.00	0.00	1.42	3.47	16.67	0.00	0.00	0.00
tra dub	2.12	5.20	16.67	4.95	6.80	50.00	6.37	6.44	66.67
vul oct	0.00	0.00	0.00	2.12	5.20	16.67	0.00	0.00	0.00

Needle-and-thread Vegetation Association

Early and Late Transient Seed Banks

Species	-----Non-infested-----			-----Infested-----			-----Bio-control-----		
	mean	std	freq	mean	std	freq	mean	std	freq
and ger	0.00	0.00	0.00	2.83	4.39	33.33	5.66	13.87	16.67
and occ	0.00	0.00	0.00	0.00	0.00	0.00	7.08	13.61	33.33
ant par	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
ant neg	1.42	3.47	16.67	0.00	0.00	0.00	0.00	0.00	0.00
Arabis	1.42	3.47	16.67	2.12	3.55	33.33	0.71	1.73	16.67
arc min	2.12	5.20	16.67	0.00	0.00	0.00	19.82	44.51	33.33
art dra	3.54	8.67	16.67	0.00	0.00	0.00	0.00	0.00	0.00
art fri	1.42	2.19	33.33	22.65	22.58	66.67	12.74	18.41	66.67
art lud	0.71	1.73	16.67	0.71	1.73	16.67	1.42	2.19	33.33
bou cur	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
bro ine	0.00	0.00	0.00	0.71	1.73	16.67	1.42	2.19	33.33
bro jap	0.00	0.00	0.00	2.83	5.14	33.33	1.42	2.19	33.33
cal lon	2.12	5.20	16.67	0.00	0.00	0.00	0.00	0.00	0.00
car fil	0.71	1.73	16.67	2.12	3.55	33.33	2.83	4.39	33.33

Table A-6 continued

carex sp	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
cha mac	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
con can	0.00	0.00	0.00	7.78	7.79	66.67	3.54	4.17	50.00
dal pur	0.00	0.00	0.00	0.71	1.73	16.67	0.71	1.73	16.67
des sop	0.00	0.00	0.00	4.25	7.11	33.33	0.00	0.00	0.00
eri fla	1.42	3.47	16.67	5.66	10.29	33.33	0.00	0.00	0.00
eri pau	0.00	0.00	0.00	13.45	20.17	50.00	0.71	1.73	16.67
ery asp	0.00	0.00	0.00	2.12	5.20	16.67	0.00	0.00	0.00
eup eus	0.00	0.00	0.00	129.51	136.88	66.67	15.57	14.63	66.67
eup spa	1.42	3.47	16.67	0.00	0.00	0.00	0.71	1.73	16.67
fra pen	2.12	5.20	16.67	2.83	5.14	33.33	2.83	6.93	16.67
fra vir	2.12	5.20	16.67	0.00	0.00	0.00	0.00	0.00	0.00
gal apr	0.71	1.73	16.67	0.00	0.00	0.00	1.42	3.47	16.67
hed his	4.25	7.11	33.33	33.97	43.30	66.67	4.95	6.25	66.67
hes com	4.95	12.13	16.67	2.12	3.55	33.33	9.91	9.93	66.67
koe mac	2.83	4.39	33.33	4.25	8.49	33.33	5.66	5.14	66.67
lac obl	0.00	0.00	0.00	0.71	1.73	16.67	0.71	1.73	16.67
lac ser	3.54	5.64	33.33	14.86	17.76	50.00	5.66	6.39	50.00
lep lat	0.00	0.00	0.00	0.71	1.73	16.67	0.00	0.00	0.00
lin per	1.42	3.47	16.67	0.00	0.00	0.00	0.00	0.00	0.00
lin rig	0.00	0.00	0.00	1.42	3.47	16.67	1.42	2.19	33.33
mel off	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
mon fis	0.00	0.00	0.00	0.00	0.00	0.00	2.12	5.20	16.67
muh rac	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
nas vir	6.37	5.85	66.67	2.12	5.20	16.67	2.83	3.47	50.00
pas smi	0.71	1.73	16.67	1.42	2.19	33.33	0.71	1.73	16.67
poa pra	2.83	6.93	16.67	3.54	6.80	33.33	26.19	40.23	50.00
rat col	4.95	6.80	50.00	1.42	3.47	16.67	0.71	1.73	16.67
sta pin	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
tar off	4.95	8.24	50.00	7.08	11.29	33.33	10.62	13.89	83.33
thl arv	0.71	1.73	16.67	2.12	3.55	33.33	1.42	2.19	33.33
tra bra	0.00	0.00	0.00	1.42	3.47	16.67	0.00	0.00	0.00
tra dub	5.66	11.91	33.33	7.78	7.79	66.67	7.08	5.80	83.33
unk brassica	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
vul oct	0.00	0.00	0.00	2.12	5.20	16.67	0.00	0.00	0.00

Needle-and-thread Vegetation Association

Persistent Seed Bank

Species	-----Non-infested-----			-----Infested-----			-----Bio-control-----		
	mean	std	freq	mean	std	freq	mean	std	freq
ama alb	0.00	0.00	0.00	0.00	0.00	0.00	0.14	1.73	16.67
and ger	0.00	0.00	0.00	1.42	3.47	16.67	1.08	0.00	0.00
Arabis	2.12	5.20	16.67	2.83	6.93	16.67	1.37	2.19	33.33
arc min	0.00	0.00	0.00	0.00	0.00	0.00	4.74	26.00	16.67
art dra	0.00	0.00	0.00	0.71	1.73	16.67	0.55	0.00	0.00
art fri	0.71	1.73	16.67	11.32	14.38	66.67	6.65	24.97	50.00
art lud	3.54	8.67	16.67	0.00	0.00	0.00	0.91	1.73	16.67
ast eri	8.49	20.80	16.67	0.00	0.00	0.00	1.12	1.73	16.67
car fil	7.78	17.07	33.33	13.45	19.99	50.00	4.21	9.30	83.33

Table A-6 continued

cer arv	2.12	5.20	16.67	0.00	0.00	0.00	0.39	1.73	16.67
che lep	3.54	4.96	50.00	2.12	2.33	50.00	1.17	6.80	33.33
con can	2.83	6.93	16.67	7.08	7.44	83.33	2.41	3.20	66.67
dal pur	7.78	19.07	16.67	2.12	5.20	16.67	1.47	1.73	16.67
des sop	0.00	0.00	0.00	2.83	3.47	50.00	2.05	15.60	16.67
ech ang	0.71	1.73	16.67	0.00	0.00	0.00	0.09	0.00	0.00
eri pau	0.71	1.73	16.67	0.00	0.00	0.00	1.31	0.00	0.00
eri str	0.71	1.73	16.67	0.00	0.00	0.00	0.09	0.00	0.00
eup eus	0.00	0.00	0.00	262.56	176.20	100.00	53.95	146.45	83.33
eup spa	15.57	36.10	33.33	0.00	0.00	0.00	5.10	19.12	50.00
gal apr	0.00	0.00	0.00	0.00	0.00	0.00	2.10	22.54	16.67
hed his	39.63	74.41	83.33	29.72	35.12	66.67	18.25	62.26	83.33
hel ann	0.71	1.73	16.67	1.42	3.47	16.67	0.96	8.67	16.67
hes com	18.40	15.81	83.33	5.66	6.39	66.67	4.61	9.46	50.00
heu ric	0.00	0.00	0.00	0.00	0.00	0.00	1.13	13.87	16.67
koe mac	12.74	29.17	33.33	0.71	1.73	16.67	3.56	7.79	33.33
lac obl	0.00	0.00	0.00	7.08	10.96	33.33	0.93	1.73	16.67
lac ser	0.71	1.73	16.67	0.00	0.00	0.00	2.56	1.73	16.67
lap squ	0.71	1.73	16.67	0.00	0.00	0.00	0.09	0.00	0.00
lep lat	0.00	0.00	0.00	0.71	1.73	16.67	0.32	1.73	16.67
lin per	0.00	0.00	0.00	0.00	0.00	0.00	0.45	3.47	16.67
mel off	2.12	5.20	16.67	0.00	0.00	0.00	0.36	0.00	0.00
nas vir	0.00	0.00	0.00	0.00	0.00	0.00	1.26	1.73	16.67
ort lut	0.71	1.73	16.67	0.00	0.00	0.00	0.09	0.00	0.00
pan cap	0.00	0.00	0.00	0.00	0.00	0.00	0.28	3.47	16.67
pas smi	8.49	10.40	50.00	3.54	5.64	33.33	3.11	10.88	50.00
pla maj	0.00	0.00	0.00	0.00	0.00	0.00	0.14	1.73	16.67
poa pra	0.00	0.00	0.00	0.00	0.00	0.00	4.32	13.87	16.67
pol pen	0.00	0.00	0.00	0.00	0.00	0.00	1.70	20.80	16.67
pot arg	0.00	0.00	0.00	0.00	0.00	0.00	0.14	1.73	16.67
pot pen	1.42	3.47	16.67	0.00	0.00	0.00	0.31	1.73	16.67
rat col	2.83	3.47	50.00	0.71	1.73	16.67	0.98	0.00	0.00
sch sco	0.71	1.73	16.67	1.42	3.47	16.67	0.54	2.19	33.33
spo cry	4.95	12.13	16.67	8.49	9.68	66.67	2.05	6.58	33.33
tar off	1.42	3.47	16.67	1.42	3.47	16.67	2.91	3.47	16.67
thl arv	4.95	12.13	16.67	16.28	35.77	50.00	2.89	1.73	16.67
tra dub	0.00	0.00	0.00	9.20	8.67	66.67	2.54	0.00	0.00
ver bra	2.12	5.20	16.67	0.00	0.00	0.00	0.96	8.67	16.67
vul oct	0.00	0.00	0.00	4.25	6.58	50.00	1.48	10.40	16.67

Needle-and-thread Vegetation Association

Dormant Seed Bank

Species	-----Non-infested-----			-----Infested-----			-----Bio-control-----		
	mean	std	freq	mean	std	freq	mean	std	freq
all tex	0.00	0.00	0.00	6.37	9.96	0.33	5.66	13.87	16.67
ara spp	0.00	0.00	0.00	2.83	5.14	0.33	0.00	0.00	0.00
art fri	5.66	13.87	16.67	29.72	50.96	0.67	5.66	10.29	33.33
astr spp	1.42	3.47	16.67	0.00	0.00	0.00	1.42	2.19	33.33
cam mic	0.00	0.00	0.00	1.42	3.47	0.17	0.71	1.73	16.67

Table A-6 continued

car fil	0.00	0.00	0.00	17.69	15.29	0.67	12.74	15.66	0.50
car sp#2	5.66	13.87	16.67	2.12	3.55	0.33	2.83	3.47	50.00
car6	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
car7	0.00	0.00	0.00	5.66	13.87	0.17	0.00	0.00	0.00
car8	0.71	1.73	16.67	0.71	1.73	0.17	0.00	0.00	0.00
car9	0.00	0.00	0.00	2.12	5.20	0.17	0.71	1.73	16.67
carex sp	0.00	0.00	0.00	0.00	0.00	0.00	1.42	3.47	16.67
che spp	119.60	143.98	83.33	407.64	255.44	1.00	157.11	140.53	100.00
cir und	0.00	0.00	0.00	0.71	1.73	0.17	0.00	0.00	0.00
col lin	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
dal pur	1.42	3.47	16.67	0.00	0.00	0.00	4.25	10.40	16.67
des pin	2.83	5.14	33.33	15.57	18.15	0.67	16.99	29.78	66.67
des sop	22.65	55.47	16.67	22.65	47.18	0.83	3.54	6.80	33.33
ery asp	0.00	0.00	0.00	22.65	55.47	0.17	3.54	8.67	16.67
ery che	0.00	0.00	0.00	0.00	0.00	0.00	1.42	3.47	16.67
eup eus	0.00	0.00	0.00	55.20	109.35	0.67	4.95	8.67	33.33
eup spa	2.12	3.55	33.33	0.00	0.00	0.00	3.54	8.67	16.67
fabaceae2	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
fabaceae3	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
fabaceae4	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
fabaceae5	0.00	0.00	0.00	0.00	0.00	0.00	2.83	6.93	16.67
fabaceae6	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
fabaceae1	0.00	0.00	0.00	0.00	0.00	0.00	4.95	12.13	16.67
hed his	2.83	5.14	33.33	22.65	33.93	0.67	13.45	23.01	66.67
hel spp	2.12	5.20	16.67	0.71	1.73	0.17	1.42	3.47	16.67
hes com	61.57	28.39	100.00	15.57	16.48	0.83	29.72	26.45	83.33
lap occ	1.42	3.47	16.67	14.15	34.67	0.17	0.00	0.00	0.00
lep den	2.83	5.14	33.33	19.11	21.10	0.83	7.08	6.93	66.67
lin lew	2.12	3.55	33.33	0.00	0.00	0.00	1.42	3.47	16.67
lin rig	0.71	1.73	16.67	0.00	0.00	0.00	0.71	1.73	16.67
lit inc	0.71	1.73	16.67	0.71	1.73	0.17	0.71	1.73	16.67
mel off	187.54	455.24	33.33	1.42	2.19	0.33	10.62	23.98	33.33
muh spp	0.00	0.00	0.00	0.71	1.73	0.17	0.00	0.00	0.00
nas vir	8.49	8.91	66.67	9.91	12.79	0.50	42.46	84.54	0.50
oen spp	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
ort lut	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
oxy lam	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
pap rho	0.00	0.00	0.00	0.71	1.73	0.17	0.00	0.00	0.00
pla elo	0.00	0.00	0.00	3.54	8.67	0.17	2.12	5.20	16.67
poa pra	0.71	1.73	16.67	0.00	0.00	0.00	4.95	10.20	33.33
pol alb	21.94	32.83	66.67	3.54	8.67	0.17	9.91	16.26	66.67
pol con	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
pot pen	0.00	0.00	0.00	0.00	0.00	0.00	12.74	31.20	16.67
ran abo	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
ran abo	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
rat col	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
scr sp#4	1.42	3.47	16.67	0.00	0.00	0.00	0.00	0.00	0.00
she arg	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00
sph coc	19.82	21.09	66.67	9.91	22.25	0.33	10.62	10.99	66.67

Table A-6 continued

spo cry	4.95	8.67	33.33	6.37	7.94	0.67	5.66	11.91	33.33
tra bra	0.00	0.00	0.00	0.71	1.73	0.17	0.00	0.00	0.00
unk spp	0.00	0.00	0.00	0.71	1.73	0.17	0.71	1.73	16.67
unk spp	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.73	16.67
Unknown	0.00	0.00	0.00	2.12	5.20	0.17	0.00	0.00	0.00
ver bra	0.71	1.73	16.67	0.00	0.00	0.00	0.00	0.00	0.00

Table A-7. Mean seed density (seed/m²) and standard deviations () of commonly occurring species in the non-infested (NI), infested (IF), and bio-control (BC) site seed banks in the silver sage vegetation association of the South Unit of Theodore Roosevelt National Park, ND. Common species are defined as a frequency of 50% or more across the plots within each site. Transient seed banks consisted of seedlings germinated from surface litter collected Sept. 2001 and June 2002 (n = 12), persistent seed banks consisted of seedlings germinated from soil core samples (n = 6), and dormant seed banks consisted of remaining un-germinated viable seed remaining in the soil core samples (n = 6).

Species	Comp ¹	Seed bank type								
		Transient ²			Persistent			Dormant		
		NI	IF	BC	NI	IF	BC	NI	IF	BC
-----seeds/m ² (std dev)-----										
<i>Androsace occidentalis</i>	f		13 (21.8)							
<i>Artemisia ludoviciana</i>	f		8 (9.1)	3 (3.5)		26 (32.2)				
<i>Chenopodium</i> spp.	f							112 (165.4)	82 (116.3)	173 (170.9)
<i>Cerastium arvense</i>	f					28 (49.1)				
<i>Collomia linearis</i>	f							5 (6.8)		
<i>Conzya canadensis</i>	f		7 (5.8)	13 (15.7)	12 (16.21)	45 (3.2)				
<i>Descurainia pinnata</i>	f							33 (43.7)	13 (13.3)	35 (41.1)
<i>Euphorbia spathulata</i>	f			4 (5.4)	52 (56.0)	35 (70.7)	90 (90.9)	21 (21.9)		33 (38.8)
<i>Hedeoma hispida</i>	f		4 (5.0)	8 (9.84)	26 (25.8)	32 (30.1)	8 (19.9)	5 (6.3)		10 (11.6)
<i>Lappula occidentalis</i>	f							6.4 (7.5)		
<i>Melilotus officinalis</i>	f							929 (1753.1)	500 (257.4)	932 (1235.3)
<i>Nasella viridula</i>	f							4 (6.6)		3 (3.5)
<i>Sphaeralcea coccinea</i>	f							14 (16.9)		
<i>Hesperostipa comata</i>	g							7 (8.4)	6 (3.5)	
<i>Pascopyron smithii</i>	g			23 (29)						
<i>Sporobolus cryptandrus</i>	g							7 (8.4)	11 (20.1)	14 (25.15)
<i>Descurainia sophia</i>	wf							9 (16.7)		20 (25.6)
<i>Euphorbia esula</i>	wf		499 (83.3)	381 (439.7)		505 (536.8)	339 (492.9)		8 (14.8)	5 (6.9)
<i>Polygonum convolvulus</i>	wf							4 (5.4)		
<i>Taraxacum officinale</i>	wf	11 (17.9)	6 (7.9)							
<i>Bromus japonicus</i>	wg		30 (56.7)		25 (56.6)					
<i>Bromus inermis</i>	wg					28 (59.3)				
<i>Poa pratensis</i>	wg	76 (76.7)	38 (29.8)	25 (31.6)		21 (27.1)	3 (20.1)	6 (7.5)	4 (3.8)	
Total species with ≥ 50%	23	2	8	7	4	8	4	14	7	9

¹Composition consists of f = native forb, g = grass/sedge, wf, wg = non-native forb or grass. Composition designations follow Barkley (1986), and Northern Great Plains Floristic Quality Assessment Panel (2001).

²Transient seed bank consists of early and late transient seed banks combined.

Table A-8. Mean seed density (seed/m²) and standard deviations () of commonly occurring species in the non-infested (NI), infested (IF), and bio-control (BC) site seed banks in the needle-and-thread vegetation association of the South Unit of Theodore Roosevelt National Park, ND. Commonly occurring species are defined as a frequency of 50% or more across the plots within each site. Transient seed banks consisted of seedlings germinated from surface litter collected Sept. 2001 and June 2002 (n = 12), persistent seed banks consisted of seedlings germinated from soil core samples (n = 6), and dormant seed banks consisted of remaining un-germinated viable seed remaining in the soil core samples (n = 6).

Species	Comp ¹	Seed bank type								
		-----Transient ² -----			-----Persistent-----			-----Dormant-----		
		NI	IF	BC	NI	IF	BC	NI	IF	BC
-----seeds/m ² (std dev)-----										
<i>Artemisia frigida</i>	f		23 (22.6)	13 (12.8)		11 (14.4)	7 (24.9)		30 (50.0)	
<i>Chenopodium</i> spp.	f				4 (4.9)	2 (2.3)		119 (141.3)	408 (255.6)	157 (140.9)
<i>Conyza canadensis</i>	f		8 (7.7)	3 (3.4)		7 (7.4)	3 (3.2)			
<i>Descurainia pinnata</i>	f								16 (18.1)	17 (29.8)
<i>Eriogonum pauciflorum</i>	f		13 (20.1)							
<i>Euphorbia spathulata</i>	f						5 (19.1)			
<i>Hedeoma hispida</i>	f		33 (43.3)	5 (6.3)	40 (74.4)	30 (35.1)	18 (62.3)		23 (33.3)	13 (23.0)
<i>Lepidium densiflorum</i>	f								19 (21.1)	7 (6.8)
<i>Polygala alba</i>	f							22 (32.2)		10 (16.3)
<i>Ratibida columnifera</i>	f	5 (6.7)			3 (3.5)					
<i>Sphaeralcea coccinea</i>	f							20 (20.1)		11 (10.9)
<i>Carex filifolia</i>	g					14 (19.9)	4 (9.3)		18 (15.0)	13 (15.4)
<i>Hesperostipa comata</i>	g			10 (9.9)	18 (15.8)	6 (6.4)	5 (9.5)	62 (27.8)	16 (16.4)	30 (26.5)
<i>Koeleria macrantha</i>	g			6 (5.1)						
<i>Nasella viridula</i>	g	6 (5.8)		3 (3.5)				9 (8.7)	10 (12.6)	43 (84.5)
<i>Pascopyron smithii</i>	g				9 (10.4)		3 (10.8)			
<i>Sporobolus cryptandrus</i>	g					9 (9.7)			6 (7.8)	
<i>Vulpia octifolia</i>	g					4 (6.6)				
<i>Descurainia sophia</i>	wf					3 (3.4)			23 (46.3)	
<i>Euphorbia esula</i>	wf		130 (136.9)	16 (14.6)		263 (176.2)	54 (146.5)		55 (109.4)	
<i>Lactuca serriola</i>	wf		15 (17.8)	6 (6.3)						
<i>Taraxacum officinale</i>	wf	5 (8.2)		11 (13.9)						
<i>Thlaspi arvense</i>	wf					16 (35.8)				
<i>Tragopogon dubius</i>	wf		8 (7.8)	7 (5.8)		9 (8.7)				
<i>Poa pratensis</i>	wg			26 (40.2)						
Total species with ≥ 50%	25	3	7	11	5	12	8	5	11	9

¹Composition consists of f = native forb, g = grass/sedge, wf, wg = non-native forb or grass. Composition designations follow the Northern Great Plains Floristic Quality Assessment Panel, (2001).

²Transient seed bank consists of early and late transient seed banks combined.

Table A-9. Mean seed density (seed/m²) and standard deviations () of commonly occurring species in the non-infested (NI), infested (IF), bio-control (BC) site seed banks in the green ash draw vegetation association of the South Unit of Theodore Roosevelt National Park, ND. Commonly occurring species are defined as a frequency of 50% or more across the plots within each site. Transient seed banks consisted of seedlings germinated from surface litter collected Sept. 2001 and June 2002 (n = 12 for non-infested and bio-control and n = 8 for infested sites) persistent seed banks consisted of seedlings germinated from soil core samples (n = 6 for non-infested and bio-control sites and n = 4 for infested sites) and dormant seed banks consisted of remaining un-germinated viable seed remaining in the soil core samples (n = 6 for non-infested and bio-control sites and n = 4 for infested sites).

Species	Comp ¹	Seed Bank Type								
		-----Transient ² -----			-----Persistent-----			-----Dormant-----		
		NI	IF	BC	NI	IF	BC	NI	IF	BC
		--- seeds/m ² (std dev)---								
<i>Amaranthus albus</i>	f	16 (17.6)	7 (8.8)	10 (18)	36 (62.5)		12 (12.2)	11 (21.2)		5 (8.1)
<i>Chenopodium</i> spp.	f				20 (28.2)		6 (9.8)	227 (375.2)	32 (29.2)	79 (78.3)
<i>Conyza canadensis</i>	f						6 (9.9)			
<i>Descurainia pinnata</i>	f							3 (3.4)		
<i>Ellisia nyctelea</i>	f									28 (45.9)
<i>Erigeron strigosus</i>	f	3 (3.5)								
<i>Galtum</i> species	f	35 (36.0)		39 (48.7)	60 (62.5)		15 (21.0)	34 (54.3)		11 (18.0)
<i>Heuchera richardsonii</i>	f				2 (2.2)					
<i>Lactuca oblongifolia</i>	f		23 (28.0)	6 (7.3)						
<i>Linum lewisii</i>	f									5 (8.2)
<i>Lysemachia ciliata</i>	f				13 (17.0)					
<i>Monarda fistulosa</i>	f			11 (14.3)			18 (35.3)			
<i>Parietaria pennsylvanica</i>	f							44 (58.8)		13 (8.7)
<i>Ranunculus abortivus</i>	f						23 (41.8)			
<i>Sphaeralcea coccinea</i>	f									7 (8.4)
<i>Carex</i> species	g				8 (10.0)					
<i>Elymus trachycaulus</i>	g		89 (150.8)							
<i>Elymus virginicus</i>	g	26 (49.9)	9 (14.7)	6 (6.4)						
<i>Muhlenbergia racemosa</i>	g		5 (6.3)	4 (6.8)						
<i>Piptatherum micranthum</i>	g				125 (300.6)			57 (102.4)		
<i>Fraxinus pennsylvanica</i>	t	72 (100.8)	144 (207.5)	21 (31.2)			15 (19.2)			
<i>Arctium minus</i>	wf	21 (34.0)			83 (145.0)			11 (18.5)		
<i>Euphorbia esula</i>	wf	16 (29.9)	180 (195.2)	16 (25)			1070 (960.2)	290 (435.1)		
<i>Lactuca serriola</i>	wf			9 (11.9)	6 (5.7)			6 (6.4)		
<i>Lappula squarrosa</i>	wf			9 (10.5)						

Table A-9 continued

<i>Melilotus officinalis</i>	wf							16 (23.0)	135 (173.5)	59 (90.1)
<i>Taraxacum officinale</i>	wf	34 (28.5)					10 (11.6)			
<i>Poa annua</i>	wg			28 (48.4)						
<i>Poa compressa</i>	wg						4 (4.9)			
<i>Poa pratensis</i>	wg	33 (22.2)	16 (24)	30 (26.4)	18 (35.1)		355 (671.6)			
Total species with ≥ 50%		30	9	8	12	10	2	12	7	2
										8

¹Composition consists of f = native forb, g = grass/sedge, t = tree, wf, wg = non-native forb or grass. Composition designations follow the Northern Great Plains Floristic Quality Assessment Panel, (2001).

²Transient seed bank consists of early and late transient seed banks combined.

Table A-10. Mean seed density (seed/m²) of non-native species documented in infested (IF), bio-control (BC) and non-infested (NI) sites in silver sage, needle-and-thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park (n = 6 for all sites except green ash draw infested sites where n = 4). Seed densities reported are sums of seed documented in transient, persistent and dormant seed bank fractions.

Species	Vegetation Association								
	Silver sage			Needle-and-thread			Green ash draw		
	NI	IF	BC	NI	IF	BC	NI	IF	BC
Major weed species									
<i>Articum minus</i>	1a (1.7)	4a (8.7)	0a (0.0)	2a (5.2)	0a (0.0)	30a (48.7)	105a (181.9)	3b (6.4)	34ab (54.3)
<i>Bromus inermis</i>	6a (11.9)	34a (58.2)	1a (1.7)	0a (0.0)	1a (1.7)	1a (2.2)	1b (3.5)	3b (6.4)	36a (86.7)
<i>Bromus japonicus</i>	40a (83.1)	135a (250.1)	0a (0.0)	0a (0.0)	3a (5.1)	1a (2.2)	52a (128.3)	0a (0.0)	13a (31.2)
<i>Camelina microcarpa</i>	14a (34.7)	0a (0.0)	24a (58.9)	0a (0.0)	1a (3.5)	1a (1.7)	1 (1.2)	0	0
<i>Descuriana pinnata</i>	33a (43.7)	13a (13.3)	35a (41.1)	3a (5.1)	16a (18.2)	17a (29.9)	3a (3.5)	2a (2.5)	0a (0.0)
<i>Euphorbia esula</i>	7b (17.3)	931a (1003.3)	724a (847.1)	0b (0.0)	447a (321.1)	164a (165.8)	18b (31.3)	822a (1163.6)	310ab (446.9)
<i>Lactuca serriola</i>	3a (6.9)	1a (2.2)	3a (5.1)	4a (6.6)	15a (17)	6a (6.9)	8ab (5.6)	3b (6.4)	17a (9.7)
<i>Melilotus officinalis</i>	931a (1754.9)	505a (258.3)	938a (1244.9)	190a (462.2)	1a (2.2)	11a (23.9)	18a (23.9)	37a (41.2)	61a (98.1)
<i>Poa compressa</i>	0 (0.0)	1 (3.5)	0 (0.0)				12a (25.6)	47a (82.5)	6a (8.8)
<i>Poa pratensis</i>	101a (121.9)	68a (56.5)	29a (28.5)	4a (6.8)	4a (3.8)	37a (57.0)	39a (40.4)	22a (15.3)	390a (668.9)
<i>Thlapsi arvense</i>	13a (31.2)	0a (0.0)	0a (0.0)	6a (11.9)	17a (37.1)	2a (3.6)			
Minor weed species									
<i>Bromus tectorum</i>	0a (0.0)	0a (0.0)	5a (12.1)						
<i>Hyoscyamus niger</i>	1 (1.7)	0 (0.0)	0 (0.0)						
<i>Lappula squarrosa</i>				0 (0.0)	0 (0.0)	0 (1.7)	6a (10.7)	0a (0.0)	9a (10.7)
<i>Lepidium densiflorum</i>	1 (1.7)	0 (0.0)	0 (0.0)						
<i>Lepidium latifolium</i>				0a (1.7)	1a (3.5)	1a (3.5)			
<i>Linum perenne</i>	18a (45.1)	0a (0.0)	3a (3.5)	1 (3.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (5.1)
<i>Lithospermum arvense</i>	1 (2.0)	0 (0.0)	0 (0.0)						
<i>Poa annua</i>	0a (0.0)	1a (1.7)	2a (5.2)				5a (12.1)	2a (4.3)	28a (49.4)
<i>Poa canbyi</i>	0 (0.0)	1 (1.7)	0 (0.0)						
<i>Polygonum</i>	6a (0.0)	11a (22.1)	0a (0.0)	0 (0.0)	0 (0.0)	1 (1.7)	11a (13.6)	0a (0.0)	1a (2.2)
<i>Salsola iberica</i>							2 (5.2)	0 (0.0)	0 (0.0)
<i>Sonchus arvensis</i>	0 (0.0)	1 (1.7)	0 (0.0)						
<i>Taraxacum officinale</i>	11a (19.7)	7a (8.4)	4a (8.7)	6a (8.8)	9a (14.2)	12a (17.3)	27a (21.1)	7a (14.9)	19a (12.8)
<i>Tragopogon dubius</i>	1a (1.7)	2a (3.6)	2a (3.6)	6a (11.9)	17a (13.4)	7a (5.8)	0a (0.0)	3a (4.1)	4a (4.7)

* Letters in common within a row for each vegetation association denote no significant differences detected at p = ≤ 0.05 using the Kruskal Wallis test.

Table A-11. Similarity indices (*J*) and baseline values (BL) between extant vegetation (ext) and seed bank (sb) species for all site combinations in the silver sage, needle-and-thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Site designations are as follows: NI = non-infested, IF = infested, and BC = infested with bio-control treatments. All comparisons were based on n = 6 except for green ash draw infested (IF) sites where n = 4.

Comparison between extant vegetation species and seed bank species by site	Silver sage		Needle-and- thread		Green Ash Draw	
	-- <i>J</i> --	--BL--	-- <i>J</i> --	--BL--	-- <i>J</i> --	--BL--
NI (ext) vs.. NI (sb)	0.17*	0.28	0.17*	0.31	0.20*	0.43
NI (ext) vs. IF (sb)	0.18*	0.33	0.19*	0.37	0.17*	0.41
NI (ext) vs. BC (sb)	0.17*	0.30	0.22*	0.36	0.21*	0.43
IF (ext) vs. IF (sb)	0.19*	0.36	0.23*	0.41	0.20*	0.39
IF (ext) vs. NI (sb)	0.16*	0.31	0.22*	0.42	0.16*	0.33
IF (ext) vs. BC (sb)	0.18*	0.33	0.17*	0.36	0.20*	0.39
BC (ext) vs. BC (sb)	0.20*	0.29	0.22*	0.33	0.20*	0.41
BC (ext) vs. NI (sb)	0.15*	0.28	0.17*	0.28	0.20*	0.41
BC (ext) vs. IF (sb)	0.18*	0.32	0.16*	0.34	0.27*	0.39

* Significant differences detected between extant and seed bank species comparisons at $p \leq 0.05$.

Table A-12. Common seed bank species (frequency of 50% or more) identified in infested (IF), bio-control (BC), and non-infested (NI) sites in the silver sage, needle-and-thread, and green ash draw vegetation associations yet no occurrences of corresponding plant(s) in the extant vegetation in the South Unit of Theodore Roosevelt National Park, ND. Seed bank species occurrences include persistent, dormant, and transient fractions combined. Seed bank fractions were collected late summer 2001 and early summer 2002, and extant vegetation data was collected early summer of 2002.

Species	Type ¹	Reprod ²	Silver sage			Needle-and-thread			Green ash draw		
			NI	IF	BC	NI	IF	BC	NI	IF	BC
<i>Androsace occidentalis</i>	f	s/a		x							
<i>Arabis</i> species	f	s/ bi, p									x
<i>Artemisia ludoviciana</i>	f	s/v/p		x	x						
<i>Conyza canadensis</i>	f	s/a					x	x			x
<i>Descuriana pinnata</i>	f	s/a		x	x		x		x		
<i>Ellisia nyctelea</i>	f	s/a,bi							x		x
<i>Hedeoma hispida</i>	f	s/a			x	x					
<i>Lepidium densiflorum</i>	f	s/a, bi						x			
<i>Parietaria pensylvanica</i>	f	s/a							x		x
<i>Polygonum douglasii</i>	f	s/a	x								
<i>Potentilla pensylvanica</i>	f	s/p	x								
<i>Psoralea argophylla</i>	f	s/v/p	x								
<i>Sphaeralcea coccinea</i>	f	s/p									x
<i>Koeleria macrantha</i>	g	s/p		x							
<i>Muhlenbergia</i> species	g	s/v/p		x	x						x
<i>Piptatherum micranthum</i>	g	s/p	x						x		x
<i>Pascopyron smithii</i>	g	s/v/p	x								
<i>Sporobolus cryptandrus</i>	g	s/p		x	x			x			
<i>Prunus virginiana</i>	t	s/v/p	x								
<i>Camelina microcarpa</i>	wf	s/a							x		
<i>Daucus carota</i>	wf	s/bi		x							
<i>Descurainia sophia</i>	wf	s/a							x		
<i>Lappula squarrosa</i>	wf	s/a									x
<i>Thlaspi arvense</i>	wf	s/a					x				
Total			6	7	5	1	3	3	6	0	8

¹Type: f = forb, s = shrub, g = grass, t = tree, wf = non-native forb.

²Reproduction type: v = vegetative, s = seed, a = annual, p = perennial, bi = biennial, b = bulb.

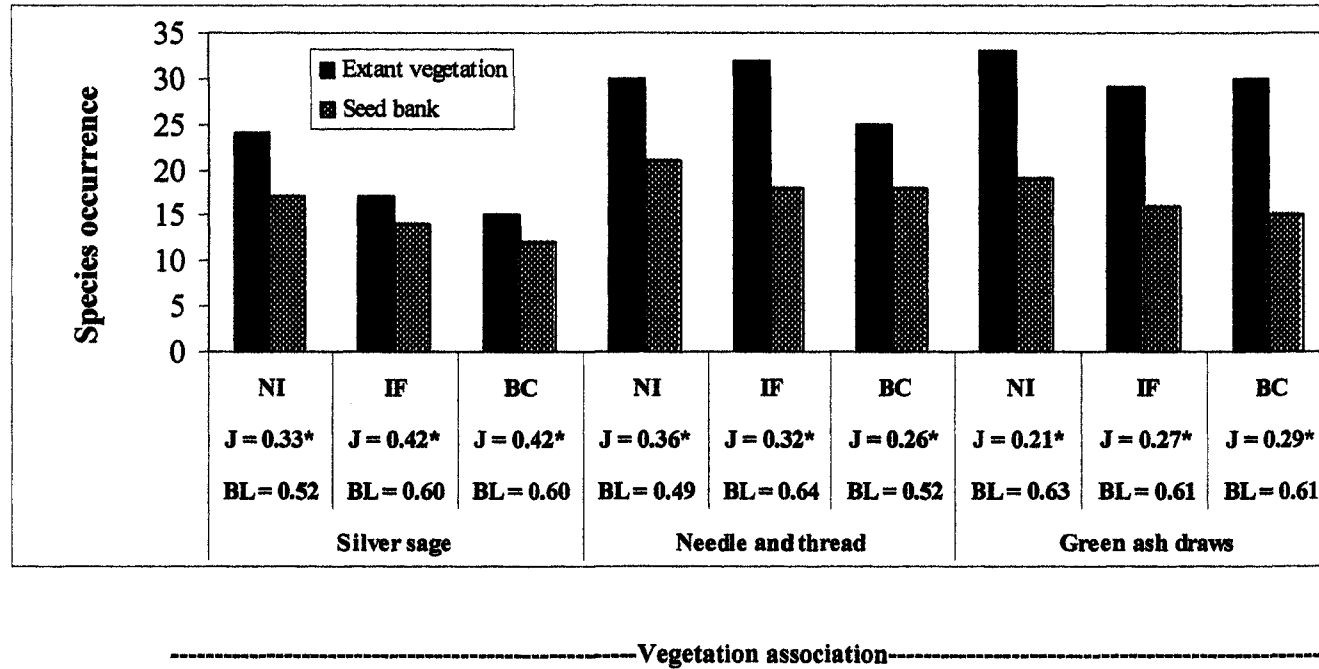


Figure A.1. Commonly occurring species in extant vegetation and the number of those species documented in corresponding seed bank in non-infested (NI), infested (IF), and bio-control sites (BC) in the silver sage, needle-and-thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. Commonly occurring extant species are defined as species with frequencies of 67% or more across plots within each site. Jaccard's similarity coefficient (J) indicates the level of similarity between the extant vegetation and seed bank species within each site. Baseline coefficients (BL) reflect the amount of similarity between species among replicates within sites. *Significant differences were detected between comparisons between the extant vegetation and seed bank species at $p \leq 0.05$.

Appendix B

Key to Species, Data Tables and Statistical Results

Table B-1. Species list from extant vegetation study and seed bank study in the South Unit of Theodore Roosevelt National Park, ND. Study date: 2001-2002. Table lists scientific name, common name, where the species was found extant = e and sb = seed bank, origin (native or introduced), and life history where a = annual, b = biennial, and p = perennial, and presence (+), absence (0).

Scientific Name	Common Name	Where ¹	Comp ²	Origin ³	Life ⁴	Extant Veg	Seed bank
<i>Acer negundo</i>	box elder	e	t	n	p	+	0
<i>Achillea millefolium</i>	western yarrow	e/sb	f	n	p	+	+
<i>Agropyron cristatum</i>	crested wheatgrass	e	g	i	p	+	0
<i>Allium textile</i>	onion	e/sb	f	n	p	+	+
<i>Amaranthus albus</i>	tumble pigweed	e/sb	f	n	a	+	+
<i>Ambrosia psilostachya</i>	western ragweed	e/sb	f	n	p	+	+
<i>Ambrosia trifida</i>	giant ragweed	e/sb	f	n	a	+	+
<i>Amelanchier alnifolia</i>	Saskatoon serviceberry	e	s	n	p	+	0
<i>Amorpha canescens</i>	leadplant	sb	s	n	p	0	+
<i>Andropogon gerardii</i>	big bluestem	e/sb	g	n	p	+	+
<i>Androsace occidentalis</i>	western rockjasmine	sb	f	n	a	0	+
<i>Anemone canadensis</i>	meadow anemone	e	f	n	p	+	0
<i>Anemone cylindrica</i>	candle anemone	e	f	n	p	+	0
<i>Antennaria neglecta</i>	field pussytoes	e/sb	f	n	p	+	+
<i>Antennaria microphylla</i>	pink pussytoes	e	f	n	p	+	0
<i>Antennaria parlinii</i>	plainlead pussytoes	e/sb	f	n	p	+	+
<i>Antennaria</i> spp.		e	f	n	p	+	0
<i>Apocynum androsaemifolium</i>	spreading dogbane	e	f	n	p	+	0
<i>Apocynum cannabinum</i>	Indian hemp dogbane	e	f	n	p	+	0
<i>Arabis</i> spp.		sb				0	+
<i>Arctium minus</i>	common burdock	e/sb	f	i	b	+	+
<i>Aristida longispica</i>	slimspike three-awn	e	g	n	a	+	0
<i>Aristida purpurea var robusta</i>	red three awb	e/sb	g	n	p	+	+
<i>Artemesia cana</i>	dwarf sagebrush	e	s	n	p	+	0
<i>Atemesia drancuniculus</i>	silky wormwood	e/sb	f	n	p	+	+
<i>Artemesia frigida</i>	fringed sagewort	e/sb	f	n	p	+	+
<i>Artemesia ludoviciana</i>	cudweed sagewort	e/sb	f	n	p	+	+
<i>Artemesia tridentata</i>	big sagebrush	e	s	n	p	+	0
<i>Artemesia</i> spp.		sb				0	+
<i>Asclepias ovalifolia</i>	ovalleaf milkweed	e	f	n	p	+	0
<i>Asclepias pumila</i>	plains milkweed	e	f	n	p	+	0
<i>Asclepias speciosa</i>	showy milkweed	e	f	n	p	+	0
<i>Asclepias viridiflora</i>	green milkweed	e	f	n	p	+	0
<i>Asclepias unknown</i>		e				+	0
<i>Aster</i> spp.		e				+	0
<i>Aster ericoides</i>	heath aster	e/sb	f	n	p	+	+

<i>Aster laevis</i>	smooth blue aster	e/sb	f	n	p	+	+
<i>Astragalus</i> spp.		e/sb				+	+
<i>Astragalus crassicaarpus</i>	ground plum	e	f	n	p	+	0
<i>Astragalus adsurgens</i>	standing milkvetch	e	f	n	p	+	0
<i>Astragalus gilviflorus</i>	plains orophaca	e/sb	f	n	p	+	+
<i>Astragalus lotiflorus</i>	lotus milkvetch	e	f	n	p	+	0
<i>Astragalus missouriensis</i>	missouri milkvetch	e	f	n	p	+	0
<i>Astragalus muttalianus</i>	milkvetch	e	f	n	a	+	0
<i>Atriplex canescens</i>	four winged saltbush	e	s	n	p	+	0
<i>Atriplex</i> spp.		e				+	0
<i>Bidens vulgate</i>	Bid devil's beggartick	e	f	n	a	+	0
<i>Bouteloua curtipendula</i>	sideouats grama	e/sb	g	n	p	+	+
<i>Bouteloua gracilis</i>	blue grama	e/sb	g	n	p	+	+
<i>Bouteloua species</i>		e				+	0
<i>Bromus inermis</i>	smooth brome	e/sb	g	i	p	+	+
<i>Bromus japonicus</i>	japanese brome	e/sb	g	i	a	+	+
<i>Bromus tectorum</i>	downy brome	e/sb	g	i	a	+	+
<i>Calamagrostis canadensis</i>	bluejoint	e	g	n	p	+	0
<i>Calamovilfa longifolia</i>	prairie sandreed	e/sb	g	n	p	+	+
<i>Calochortus nuttallii</i>	sego lily	e	f	n	p	+	0
<i>Calylophus serrulatus</i> (Syn. <i>Oenothera serrulata</i>)	plains yellow primrose	e	f	n	p	+	0
<i>Calystegia sepium</i> (Syn. <i>Convolvulus sepium</i>)	hedge bindweed	e	f	n	p	+	0
<i>Camelina microcarpa</i>	littlepod false flax	e/sb	f	l	a	+	+
<i>Campanula rotundifolia</i>	harebell	e	f	n	p	+	0
<i>Capsella bursa-pastoris</i>	shepherd's purse	e	f	i	a	+	0
<i>Carex brevior</i>	fescue sedge	sb	sdge	n	p	0	+
<i>Carex duriuscula</i> (Syn. <i>C. eleocharis</i>)	needleleaf sedge	c	sdge	n	p	+	0
<i>Carex filifolia</i>	threadleaf sedge	e/sb	sdge	n	p	+	+
<i>Carex gravida</i> var <i>gravida</i>	heavy sedge	e/sb	sdge	n	p	+	+
<i>Carex interior</i>	interior sedge	sb	sdge	n	p	0	+
<i>Carex pendunculata</i>	bristleleaf sedge	sb	sdge	n	p	0	+
<i>Carex sprengelii</i>	longpeak sedge	e/sb	sdge	n	p	+	+
<i>Celastrus scandens</i>	American bittersweet	e	v	n	p	+	0
<i>Cerastium arvense</i>	prairie chickweed	e/sb	f	n	p	+	+
<i>Cerastium</i> spp.		sb				0	+
<i>Chamaesyce maculata</i>	prostrate spurge	sb	f	n	a	0	+
<i>Chenopodium album</i> (Syn. <i>C. lanceolata</i>)	common lambsquarter	e	f	i	a	+	0
<i>Chenopodium fremontii</i>	fremont goosefoot	sb	f	n	a	0	+
<i>Chenopodium gigantospermum</i>	maple leaf goosefoot	e/sb	f	n	a	+	+

<i>Chenopodium leptophyllum</i>		e/sb	f	n	p	+	+
<i>Chenopodium</i> spp.		sb				0	+
<i>Chrysopsis villosa</i>	hairy goldaster	e	f	n	p	+	0
<i>Chrysothamnus nauseosus</i>	rabbitbrush	e	s	n	p	+	0
<i>Cirsium arvense</i>	Canada thistle	e	f	i	p	+	0
<i>Cirsium undulatum</i>	wavyleaf thistle	e/sb	f	n	p	+	+
<i>Clematis ligusticifolia</i>	Western clematis	e	v	n	p	+	0
<i>Clematis virginiana</i>	virgin's bower	e	v	n	p	+	0
<i>Collomia linearis</i>	slenderleaf collomia	e/sb	f	n	a	+	+
<i>Comandra pallida</i>	pale bastard toadflax	e	f/ss/s	n	p	+	0
<i>Comandra umbellata</i>	bastard toadflax	e	f	n	p	+	0
<i>Convolvulus arvensis</i>	field bindweed	e	f	l	p	+	0
<i>Conyza canadensis</i>	horseweed	e/sb	f	n	a	+	+
<i>Coryphantha missouriensis</i>	Missouri foxtail cactus	e	f	n	p	+	0
<i>Coryphantha vivipara</i>	ball cactus	e	f	n	p	+	0
<i>Crateagus chrysocarpa</i> (Syn. <i>C. rotundiflora</i>)	Northern hawthorn	e	s	n	p	+	0
<i>Dalea candida</i>	white prairie clover	e	f	n	p	+	0
<i>Dalea purpurea</i>	purple prairie clover	e/sb	f	n	p	+	+
<i>Daucus carota</i>	wild carrot	sb	f	l	b	0	+
<i>Descuriana pinnata</i>	tansy mustard	sb	f	n	a	0	+
<i>Descurainia sophia</i>	flixweed	e/sb	f	l	a/b	+	+
<i>Distichlis spicata</i>	inland saltgrass	e	g	n	p	+	0
<i>Disporum trachycarpum</i>	fairly bells	e	f	n	p	+	0
<i>Echinacea angustifolia</i>	purple coneflower	e/sb	f	n	p	+	+
<i>Ellisia nyctelea</i>	waterpod	sb	f	n	a	0	+
<i>Elymus canadensis</i>	Canada wildrye	e	g	n	p	+	0
<i>Elymus repens</i> (Syn. <i>Agropyron repens</i>)	quackgrass	e	g	i	p	+	0
<i>Elymus trachycaulus</i> (Syn. <i>Agropyron trachycaulus</i>)	slender wheatgrass	e/sb	g	n	p	+	+
<i>Elymus virginicus</i>	Virginia wildrye	e/sb	b	n	p	+	+
<i>Equisetum</i> spp.		e				+	0
<i>Erigeron canus</i>	hoary canus	sb	f	n	p	0	+
<i>Erigeron speciosus</i>	aspen fleabane	e	f	n	p	+	0
<i>Erigeron strigosus</i>	daisy fleabane	e/sb	f	n	b	+	+
<i>Eriogonum flavum</i>	yellow wild buckwheat	e/sb	f	n	p	+	+
<i>Eriogonum pauciflorum</i>	fewflower buckwheat	e/sb	f	n	p	+	+
<i>Erysimum cheiranthoides</i>	wormseed wallflower	sb	f	i	a	0	+
<i>Erysimum asperum</i>	western wallflower	e/sb	f	n	b	+	+
<i>Euphorbia glyptosperma</i>	ridgeseed spurge	sb	f	n	a	+	+
<i>Euphorbia esula</i>	leafy spurge	e/sb	f	l	p	+	+
<i>Euphorbia spathulata</i>	prairie spurge	e/sb	f	n	a	+	+

<i>Fritillaria atropurpurea</i>	leopard lily	e	f	n	p	+	0
<i>Fragaria vesca</i> var <i>americana</i>	woodland strawberry	e/sb	f	n	p	+	+
<i>Fragaria virginiana</i>	Virginia strawberry	e/sb	f	n	p	+	+
<i>Fraxinus pennsylvanica</i>	greenash	e/sb	t	n	p	+	+
<i>Galium aparine</i>	catchweed bedstraw	e/sb	f	n	a	+	+
<i>Galium boreal</i>	northern bedstraw	e/sb	f	n	p	+	+
<i>Gaura coccinea</i>	scarlet gaura	e	f	n	p	+	0
<i>Geum triflorum</i>	torch flower	e/sb	f	n	p	+	+
<i>Glycyrrhiza lepidota</i>	wild licorice	e	f	n	p	+	0
<i>Grindelia squarrosa</i>	gumweed	e	f	n	b	+	0
<i>Gutierrezia sarothrae</i>	snakeweed	e	s	n	p	+	0
<i>Hackelia deflexa</i>	nodding sticktight	e	f	n	b/p	+	0
<i>Hedeoma hispida</i>	rough false pennyroyal	e/sb	f	n	a	+	+
<i>Helianthus annuus</i>	sunflower	e/sb	f	n	a	+	+
<i>Helianthus</i> spp.		e/sb				+	+
<i>Helianthus rigidus</i>	stiff sunflower	e	f	n	p	+	0
<i>Hesperostipa comata</i> (Syn. <i>Stipa comata</i>)	needle and thread	e/sb	g	n	p	+	+
<i>Hesperostipa spartea</i> (Syn. <i>Stipa spartea</i>)	porcupinegrass	sb	g	n	p	0	0
<i>Heuchera richardsonii</i>	Alumroot	e/sb	f	n	p	+	+
<i>Hordeum jubatum</i>	foxtail barley	e	g	n	a	+	0
<i>Humulus lupulus</i>	common hops	e	v	n	p	+	0
<i>Hymenoxys acaulis</i>	stemless hymenoxis	e	f	n	p	+	0
<i>Hyoscyamus niger</i>	Henbane	sb	f	i	a	0	+
<i>Juniperus communis</i>	common juniper	e	s	n	p	+	0
<i>Juniperus horizontalis</i>	dwarf juniper	e	s	n	p	+	0
<i>Juniperus scopulorum</i>	Rocky Mountain juniper	e	t	n	p	+	0
<i>Juncus torreyi</i>	Torrey's rush	sb	f	n	p	0	+
<i>Koeleria macrantha</i>	Junegrass	e/sb	g	n	p	+	+
<i>Koeleria pyramidata</i>	Junegrass	e	g	n	p	+	0
<i>Krashkinnikovia lanata</i> (Syn. <i>Ceratoides lanata</i>)	Winterfat	e	s	n	p	+	0
<i>Lactuca oblongifolia</i>	blue lettuce	e/sb	f	n	p	+	+
<i>Lactuca serriola</i>	prickly lettuce	e/sb	f	i	a	+	+
<i>Lappula occidentali</i> (Syn. <i>L. redowskii</i>)	Western sticktight	e/sb	f	n	a	+	+
<i>Lappula squarrosa</i> (Syn. <i>L. echinata</i>)	sticktight (blueburr)	sb	f	i	a	0	+
<i>Lepidium densiflorum</i>	Peppergrass	e/sb	f	n	a	+	+
<i>Lepidium latifolium</i>	perennial pepperweed	sb	f	i	p	0	+
<i>Lesquerella arenosa</i>	great plains bladderpod	sb	f	n	b, p	0	+
<i>Lesquerella ludoviciana</i>	foothills bladderpod	e	f	n	p	+	0

<i>Liatris punctata</i>	dotted blazing star	e	f	n	p	+	0
<i>Linum lewisii</i>	prairie flax	e/sb	f/ss/s	n	p	+	+
<i>Linum perenne</i>	blue flax	e/sb	ss/s	i	p	+	+
<i>Linum rigidum</i>	stiffstem yellow flax	e/sb	f	n	a	+	+
<i>Lithospermum arvense</i> (Syn. <i>Buglossoides arvense</i>)	corn gromwell	sb	f	i	a	0	+
<i>Lithospermum incisum</i>	narrow leaf puccoon	e/sb	f	n	p	+	+
<i>Lotus purshianus</i>	prairie trefoil	e/sb	f	n	a	+	+
<i>Lygodesmia juncea</i>	skeletonweed	e	f	n	p	+	0
<i>Lysemachia ciliata</i>	fringed loosestrife	e/sb	f	n	p	+	+
<i>Medicago lupulina</i>	black medick	e	f	i	p	+	0
<i>Melilotus officinalis</i>	yellow sweet clover	e/sb	f	i	a	+	+
<i>Monarda fistulosa</i>	wild bergmont	sb	f	n	p	0	+
<i>Muhlenbergia cuspidata</i>	plains muhly	e	g	n	p	+	0
<i>Muhlenbergia racemosa</i>	marsh muhly	e/sb	g	n	p	+	+
<i>Muhlenbergia</i> spp.		e/sb	g			+	+
<i>Nasella viridula</i> (Syn. <i>Stipa viridula</i>)	green needlegrass	e/sb	g	n	p	+	+
<i>Oenothera</i> spp.		sb				0	+
<i>Oenothera villosa</i>	common evening primrose	e	f	n	b	+	0
<i>Oenothera caespitosa</i>	gumbo evening primrose	e	f	n	p	+	0
<i>Opuntia polyacantha</i>	plains prickly pear	e	s	n	p	+	0
<i>Opuntia</i> spp.		e	s	n	p	+	0
<i>Orthocarpus luteus</i>	owl clover	e/sb	f	n	a	+	+
<i>Oryzopsis hymenopsis</i> (Syn. <i>Achnatherum hymenoides</i>)	Indian ricegrass	e	g	n	p	+	0
<i>Piptatherum micranthum</i> (Syn. <i>Oryzopsis micrantha</i>)	little-seeded ricegrass	e/sb	g	n	p	+	+
<i>Osmorrhiza longistylis</i>	sweet cicely	e	f	n	p	+	0
<i>Oxalis stricta</i>	yellow wood sorrel	e	f	n	p	+	0
<i>Oxytropis lambertii</i>	locoweed	sb	f	n	p	0	+
<i>Panicum capillare</i>	common witchgrass	sb	g	n	a	0	+
<i>Papaver dubium</i>	longhead poppy	sb	f	n	a	0	+
<i>Papaver rhoeas</i>	field poppy	sb	f	n	a	0	+
<i>Parietaria pennsylvanica</i>	Pennsylvanis pellitory	sb	f	n	a	0	+
<i>Parthenocissus vitacea</i>	woodbine (thicket creeper)	e	ss/v	n	p	+	0
<i>Pascopyron smithii</i> (Syn. <i>Agropyron smithii</i>)	western wheatgrass	e/sb	g	n	p	+	+
<i>Penstemon erianthus</i>	crested beardtounge	e	f	n	p	+	0
<i>Penstemon</i> spp.		e				+	0
<i>Phlox hoodii</i>	moss phlox	e	f	n	p	+	0
<i>Plantago elongate</i>	slender plantain	e/sb	f	n	a	+	+
<i>Plantago major</i>	common plantain	e/sb	f	i	p	+	+

<i>Plantago patagonica</i>	Patagonian plantain	e/sb	f	n	a	+	+
<i>Poa annua</i>	annual bluegrass	e/sb	g	i	a	+	+
<i>Poa canbyi</i>	canby's bluegrass	e/sb	g	i	p	+	+
<i>Poa compressa</i>	Canada bluegrass	e/sb	g	i	p	+	+
<i>Poa pratensis</i>	Kentucky bluegrass	e/sb	g	i	p	+	+
<i>Poa</i> spp.		e	g			+	0
<i>Polygala alba</i>	white milkwort	e/sb	f	n	p	+	+
<i>Polygonatum biflorum</i>	smooth Solomon's seal.	e	f	n	p	+	0
<i>Polygonum convolvulus</i>	wild buckwheat	e/sb	v	i	a	+	+
<i>Polygonum douglasii</i>	knotweed	e/sb	f	n	a	+	+
<i>Polygonum erectum</i>	erect knotweed	sb	f	n	a	0	+
<i>Polygonum pennsylvanicum</i>	Pennsylvania snartweed	sb	f	n	a	0	+
<i>Polygonum</i> spp.		e				+	0
<i>Populus deltoids</i>	eastern cottonwood	e	t	n	p	+	0
<i>Potentilla argula</i>	tall cinquefoil	sb	f	n	p	+	+
<i>Potentilla fruticosa</i>	shrubby cinquefoil	e	s	n	p	+	0
<i>Potentilla pensylvanica</i>	cinquefoil	e/sb	f	n	p	+	+
<i>Prunus americana</i>	wild plum	e	s	n	p	+	0
<i>Prunus pennsylvanica</i>	pen cherry	e	t	n	p	+	0
<i>Prunus virginiana</i>	chockcherry	e	s	n	p	+	0
<i>Psorales argophylla</i>	silverleaf scurfpea	e/sb	f	n	p	+	+
<i>Psorales esculenta</i>	Indian breadroot	e	f	n	p	+	0
<i>Ranunculus abortivus</i>	early wood buttercup	e/sb	f	n	b	+	+
<i>Ratibida columnifera</i>	long-head coneflow	e/sb	f	n	p	+	+
<i>Rhus aromatica</i>	skunkbrush	e	s	n	p	+	0
<i>Ribes aureum</i> (Syn. <i>Ribes odoratum</i>)	golden current	e/sb	s	n	p	+	+
<i>Ribes missouriensis</i>	Missouri gooseberry	e	s	n	p	+	0
<i>Ribes oxycanthoides</i> (Syn. <i>R. setosum</i>)	bristly gooseberry	e	s	n	p	+	0
<i>Rosa arkansana</i>	prairie wild rose	e	s	n	p	+	0
<i>Rosa woodsii</i>	western wild rose	e	s	n	p	+	0
<i>Rosa</i> spp.		e	s	n	p	+	0
<i>Rubus idaeus</i>	red raspberry	e	s	n	p	+	0
<i>Salsola iberica</i>	russian thistle	e/sb	f	i	a	+	+
<i>Sarcobatus vermiculatus</i>	greasewood	e	s	n	p	+	0
<i>Schizachyrium scoparium</i>	little bluestem	e/sb	g	n	p	+	+
<i>Selaginella densa</i>	small clubmoss	e	fern	n	p	+	0
<i>Senecio integerrimus</i>	lambstongue groundsel	e	f		b/p	+	0
<i>Setaria veridis</i>	green foxtail	sb	g	i	a	0	+
<i>Shepherdia argentea</i>	silver buffaloberry	e/sb	s	n	p	+	+
<i>Shepherdia canadensis</i>	rabbitberry	e	s	n	p	+	0
<i>Silene antirrhina</i>	sleepy catchfly	sb	f	i	a	0	+

<i>Sisyrinchium</i> spp.		e	f		p	+	0
<i>Maianthemum stellata</i> (Syn. <i>Smilacina stellata</i>)	false solomon seal	e	f	n	p		
<i>Solidago missouriensis</i>	Prairie goldenrod	e/sb	f	n	p	+	+
<i>Solidago mollis</i>	soft goldenrod	e/sb	f	n	p	+	+
<i>Solidago rigida</i>	stiff goldenrod	e/sb	f	n	p	+	+
<i>Solidago</i> spp.		e/sb				+	+
<i>Solanum trifolium</i>	cutleaf nightshade	e/sb	f	n	a	+	+
<i>Sonchus arvensis</i>	perennial sow thistle	sb	f	i	p	0	+
<i>Sphaeralcea coccinea</i>	scarlet globemallow	e/sb	f	n	p	+	+
<i>Sporobolus cryptandrus</i>	sand dropseed	e/sb	g	n	p	+	+
<i>Stanleya pinnata</i>	prince's plume	sb	f	n	p	0	+
<i>Symphoricarpos occidentalis</i>	buckbrush; snowberry	e/sb	s	n	p	+	+
<i>Taraxacum officinale</i>	Dandelion	e/sb	f	i	p	+	+
<i>Thlaspi arvense</i>	pennycress	e/sb	f	i	a	+	+
<i>Thalictrum dasycarpum</i>	purple meadow rue	e/sb	f	n	p	+	+
<i>Themopsis rhombifolia</i>	golden pea	e	f	n	p	+	0
<i>Toxicodendron rydbergii</i>	poison ivy	e/sb	s	n	p	+	+
<i>Tradescantia bracteata</i>	bracted spiderwort	e/sb	f	n	p	+	+
<i>Tragopogon dubius</i>	salsify	e/sb	f	i	b	+	+
<i>Urtica dioica</i>	stinging nettle	e/sb	f	n	p	+	+
<i>Verbena bracteata</i>	prostrate (bracted) vervain	sb	f	n	a/p	0	+
<i>Vicia Americana</i>	American vetch	e/sb	v	n	p	+	+
<i>Viola</i> spp.		sb				0	+
<i>Vitis vulpine</i>	winter grape	e	v	n	p	+	0
<i>Vulpia octiflora</i> (Syn. <i>Festuca octifolia</i>)	six-weeks fescue	e/sb	g	n	a	+	+
<i>Yucca glauca</i>	yucca	e	s	n	p	+	0

¹ e = extant vegetation, sb = seed bank

² Composition, where f = forb, g = grass/sedges, s = shrub, t = tree, v = vine

³ n = native, i = introduced (Northern Great Plains Floristic Quality Assessment Panel, 2001).

⁴ Life history, where p = perennial, a = annual, b = biennial

Table B-2. Mean extant species richness for non-infested, infested and bio-control sites (100m² and 1000m² plots) in silver sage, needle-and-thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND.

-----1000 m ² plot-----			
Vegetation association	Site	Richness	Std dev
Silver sage	Infested	30	5.45
Silver sage	Non-infested	38	12.6
Silver sage	Bio-control	29	6.9
Needle-and-thread	Infested	44	5.4
Needle-and-thread	Non-infested	44	9.7
Needle-and-thread	Bio-control	40	8.4
Green ash draw	Infested	47	5.7
Green ash draw	Non-infested	48	10.5
Green ash draw	Bio-control	43	6.7

-----100 m ² plot-----			
Vegetation association	Site	Richness	Std dev
Silver sage	Infested	21	7.7
Silver sage	Non-infested	23	9.9
Silver sage	Bio-control	18	4.0
Needle-and-thread	Infested	26	3.1
Needle-and-thread	Non-infested	23	4.2
Needle-and-thread	Bio-control	21	6.1
Green ash draw	Infested	31	18.2
Green ash draw	Non-infested	25	1.0
Green ash draw	Bio-control	31	6.2

Table B-2.1 Kruskal Wallis one factor rank test results for species richness for non-infested, infested, and bio-control sites (1000m² plots) in silver sage, needle-and-thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park ND.

Silver Sage			
Kruskal-Wallis statistic (adjusted for ties) testing		1.78 (asymptotic p = 0.410).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal..	
Mean Rank	Group	Infested	Non-infested
8.7	Bio-control	p > 0.20	p > 0.20
8.0	Infested		p > 0.20
11.8	Non-infested		

Needle-and-thread			
Kruskal-Wallis statistic (adjusted for ties) testing		1.33 (asymptotic p = 0.514).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
7.6	Bio-control	p > 0.20	p > 0.20
11.1	Infested		p > 0.20
9.8	Non-infested		

Table B.2.1 continued

Green Ash draw			
Kruskal-Wallis statistic (adjusted for ties) testing		0.97 (asymptotic $p = 0.615$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
7.0	Bio-control	$p > 0.20$	$p > 0.20$
9.6	Infested		$p > 0.20$
9.3	Non-infested		

Table A3.2 Kruskal Wallis One factor rank test results from species richness for non-infested, infested, and bio-control sites (100 m² plots) in silver sage, needle-and-thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park ND.

Silver Sage			
Kruskal-Wallis statistic (adjusted for ties) testing		.99 (asymptotic $p = 0.608$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
7.8	Bio-control	$p > 0.20$	$p > 0.20$
9.8	Infested		$p > 0.20$
10.8	Non-infested		

Needle-and-thread			
Kruskal-Wallis statistic (adjusted for ties) testing		1.78 (asymptotic $p = 0.411$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
7.4	Bio-control	$p > 0.20$	$P > 0.20$
11.5	Infested		$P > 0.20$
9.6	Non-infested		

Green Ash draw			
Kruskal-Wallis statistic (adjusted for ties) testing		2.67 (asymptotic $p = 0.263$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Bio-control	Non-infested
11.0	Infested	$0.05 < p < 0.10$	$p > 0.20$
6.2	Bio-control		$p > 0.20$
9.2	Non-infested		

Table. B-3. Mean Shannon-Weiner Diversity index (H') for extant species in infested, non-infested and bio-control sites in green ash draw, needle-and-thread and silver sage vegetation association in the South Unit of Theodore Roosevelt National Park, ND.

Vegetation association	Sites	H'	Std dev
Silver sage	Infested	2.06	0.20
Silver sage	Non-infested	2.19	0.29
Silver sage	Bio-control	2.02	0.20
Needle-and-thread	Infested	2.21	0.34
Needle-and-thread	Non-infested	2.18	0.57
Needle-and-thread	Bio-control	2.35	0.41
Green ash draw	Infested	2.72	0.39
Green ash draw	Non-infested	2.48	0.33
Green ash draw	Bio-control	2.53	0.52

Table B-3.1. Kruskal Wallis One factor rank test results for species richness in non-infested, infested, and bio-control sites in green ash draw, needle-and-thread and silver sage vegetation associations in the South Unit of Theodore Roosevelt National Park, ND.

Silver Sage			
Kruskal-Wallis statistic (adjusted for ties) testing		0.98 (asymptotic p = 0.612).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
8.2	Bio-control	p > 0.20	p > 0.20
9.2	Infested		p > 0.20
11.2	Non-infested		
Needle-and-thread			
Kruskal-Wallis statistic (adjusted for ties) testing		0.5 (asymptotic p = 0.777).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.7	Bio-control	p > 0.20	p > 0.20
8.5	Infested		p > 0.20
9.3	Non-infested		
Green Ash draw			
Kruskal-Wallis statistic (adjusted for ties) testing		1.0 (asymptotic p = 0.607).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
8.2	Bio-control	p > 0.20	p > 0.20
10.5	Infested		p > 0.20
7.5	Non-infested		

Table B-4. Mean extant species richness by composition (forb, grass, shrub, tree, non-native grass and non-native forb for infested, non-infested and bio-control sites in green ash draw, needle-and-thread and silver sage vegetation associations in the South Unit of Theodore Roosevelt National Park, ND.

Vegetation association	Sites	Forb	Std dev	Graminoid	Std dev	Shrub	Std dev	Tree	Std dev	Non-native grass	Std dev	Non-native forb	Std dev
Silver sage	Infested	16.2	4.36	9.3	2.30	4.2	0.75	0.3	0.82	3.0	0.63	5.5	2.26
Silver sage	Non-infested	25.2	7.8	9.2	3.10	4.0	1.80	0.3	0.52	3.2	0.98	5.7	1.37
Silver sage	Bio-control	16.5	4.97	9.3	2.73	3.7	1.37	0.8	0.98	2.2	1.69	4.8	1.94
Needle-and-thread	Infested	31.2	4.96	10.3	1.51	3.2	1.17	0.0	0.00	1.0	0.83	4.3	2.25
Needle-and-thread	Infested	31.2	4.96	10.3	1.51	3.2	1.17	0.0	0.00	0.8	0.75	4.3	2.25
Needle-and-thread	Non-infested	30.5	5.28	10.3	2.25	3.3	2.58	0.0	0.00	1.0	0.89	5.0	1.41
Needle-and-thread	Bio-control	27.3	5.28	8.6	2.07	4.0	2.76	0.2	0.41	1.3	1.03	4.3	2.25
Green ash draw	Infested	29.0	5.71	9.0	0.82	7.3	0.50	2.0	0.82	2.5	1.29	5.5	1.92
Green ash draw	Non-infested	31.3	7.7	7.5	2.66	6.6	1.20	2.2	0.98	2.0	0.00	4.0	1.67
Green ash draw	Bio-control	26.8	4.9	6.2	1.60	7.5	1.05	2.5	0.55	1.5	0.55	4.7	0.82

Table B-4.1 Kruskal Wallis One factor rank test results from compositional extant species richness for non-infested, infested, and bio-control sites in green ash draw, needle-and-thread and silver sage vegetation associations in the South Unit of Theodore Roosevelt National Park, ND.

Green Ash draw-Forbs			
Kruskal-Wallis statistic (adjusted for ties) testing		0.78 (asymptotic p =	
Ho: group effects are equal.		0.676).	
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
7.3	Bio-control	p > 0.20	p > 0.20
8.4	Infested		p > 0.20
9.8	Non-infested		
Green Ash draw-Grass			
Kruskal-Wallis statistic (adjusted for ties) testing		4.01 (asymptotic p =	
Ho: group effects are equal.		0.135).	
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
6.0	Bio-control	p > 0.20	p > 0.20
12.0	Infested		p > 0.20
8.7	Non-infested		
Green Ash draw-Shrubs			
Kruskal-Wallis statistic (adjusted for ties) testing		1.57 (asymptotic p = 0.457).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.0	Bio-control	p > 0.20	p > 0.20
8.9	Infested		p > 0.20
6.8	Non-infested		
Green Ash draw-Trees			
Kruskal-Wallis statistic (adjusted for ties) testing		0.96 (asymptotic p = 0.618.)	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.8	Bio-control	p > 0.20	p > 0.20
7.0	Infested		p > 0.20
8.3	Non-infested		
Green Ash draw-Non-native Grass			
Kruskal-Wallis statistic (adjusted for ties) testing		3.79 (asymptotic p =	
Ho: group effects are equal.		0.151).	
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
6.0	Bio-control	p > 0.20	0.10 < p < 0.20
10.8	Infested		p > 0.20
9.5	Non-infested		

Table B-4.1 continued

Green Ash draw-Non-native Forbs			
Kruskal-Wallis statistic (adjusted for ties) testing		1.79 (asymptotic p = 0.408).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
8.3	Bio-control	p > 0.20	p > 0.20
11.0	Infested		p > 0.20
7.0	Non-infested		
Needle-and-thread-Forbs			
Kruskal-Wallis statistic (adjusted for ties) testing		1.6 (asymptotic p = 0.450).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
7.3	Bio-control	p > 0.20	p > 0.20
11.1	Infested		p > 0.20
10.1	Non-infested		
Needle-and-thread-Grass			
Kruskal-Wallis statistic (adjusted for ties) testing		2.79 (asymptotic p = 0.248).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
6.6	Bio-control	p > 0.20	p > 0.20
11.3	Infested		p > 0.20
10.7	Non-infested		
Needle-and-thread-Shrubs			
Kruskal-Wallis statistic (adjusted for ties) testing		0.6 (asymptotic p = 0.739).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.8	Bio-control	p > 0.20	p > 0.20
9.1	Infested		p > 0.20
8.6	Non-infested		
Needle-and-thread-Trees			
Kruskal-Wallis statistic (adjusted for ties) testing		2.0 (asymptotic p = 0.368).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.5	Bio-control	p > 0.20	p > 0.20
9.0	Infested		p > 0.20
9.0	Non-infested		

Table B-4.1 continued

Needle-and-thread-Non-native Grass			
Kruskal-Wallis statistic (adjusted for ties) testing		0.76 (asymptotic p = 0.685).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.8	Bio-control	p > 0.20	p > 0.20
8.3	Infested		p > 0.20
9.3	Non-infested		
Needle-and-thread-Non-native Forbs			
Kruskal-Wallis statistic (adjusted for ties) testing		2.48 (asymptotic p = 0.29).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
7.3	Bio-control	p > 0.20	p > 0.20
12	Infested		p > 0.20
9.3	Non-infested		
Silver sage-Forbs			
Kruskal-Wallis statistic (adjusted for ties) testing		5.51 (asymptotic p = 0.06).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
7.4	Bio-control	p > 0.20	0.10 < p < 0.20
7.4	Infested		0.05 < p < 0.10
13.7	Non-infested		
Silver sage-Grass			
Kruskal-Wallis statistic (adjusted for ties) testing		0.01 (asymptotic p = 0.99).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.5	Bio-control	p > 0.20	p > 0.20
9.3	Infested		p > 0.20
9.7	Non-infested		
Silver sage-Shrubs			
Kruskal-Wallis statistic (adjusted for ties) testing		0.4 (asymptotic p = 0.82).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
8.8	Bio-control	p > 0.20	p > 0.20
10.6	Infested		p > 0.20
9.1	Non-infested		

Table B-4.1 continued

Silver sage-Trees			
Kruskal-Wallis statistic (adjusted for ties) testing		1.47 (asymptotic p = 0.48).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
11.3	Bio-control	p > 0.20	p > 0.20
8.3	Infested		p > 0.20
9.0	Non-infested		
Silver sage-Non-native Grass			
Kruskal-Wallis statistic (adjusted for ties) testing		3.01 (asymptotic p = 0.22).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
6.6	Bio-control	p > 0.20	p > 0.20
10.5	Infested		p > 0.20
11.4	Non-infested		
Silver sage-Non-native Forbs			
Kruskal-Wallis statistic (adjusted for ties) testing		0.39 (asymptotic p = 0.82).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
8.4	Bio-control	p > 0.20	p > 0.20
9.9	Infested		p > 0.20
10.2	Non-infested		

Table B-5. Mean seed bank species richness for non-infested, infested and bio-control sites in green ash draw, needle-and-thread and silver sage vegetation types in the South Unit of Theodore Roosevelt National Park, ND.

Vegetation type	Treatment	Seed bank	Richness	Std dev
Silver sage	Infested	Early Tran	6	2.2
Silver sage	Non-infested	Early Tran	3	1.7
Silver sage	Bio-control	Early Tran	5	2.3
Silver sage	Infested	Late Tran	9	3.6
Silver sage	Non-infested	Late Tran	8	5.0
Silver sage	Bio-control	Late Tran	7	3.9
Silver sage	Infested	Persistent	12	3.8
Silver sage	Non-infested	Persistent	12	6.4
Silver sage	Bio-control	Persistent	7	2.0
Silver sage	Infested	Dormant	11	3.0
Silver sage	Non-infested	Dormant	15	6.6
Silver sage	Bio-control	Dormant	12	2.3
Silver sage	Infested	Total SB	10	3.7
Silver sage	Non-infested	Total SB	9	6.9
Silver sage	Bio-control	Total SB	8	3.5
Needle-and-thread	Infested	Early Tran	5	1.0
Needle-and-thread	Non-infested	Early Tran	4	2.7
Needle-and-thread	Bio-control	Early Tran	5	2.8
Needle-and-thread	Infested	Late Tran	9	3.9
Needle-and-thread	Non-infested	Late Tran	4	1.4
Needle-and-thread	Bio-control	Late Tran	9	3.3
Needle-and-thread	Infested	Persistent	10	4.2
Needle-and-thread	Non-infested	Persistent	8	5.8
Needle-and-thread	Bio-control	Persistent	11	2.5
Needle-and-thread	Infested	Dormant	12	4.5
Needle-and-thread	Non-infested	Dormant	9	5.3
Needle-and-thread	Bio-control	Dormant	14	3.1
Needle-and-thread	Infested	Total SB	10	4.4
Needle-and-thread	Non-infested	Total SB	6	4.5
Needle-and-thread	Bio-control	Total SB	10	4.3
Green Ash Draw	Infested	Early Tran	3	1.3
Green Ash Draw	Non-infested	Early Tran	7	1.6
Green Ash Draw	Bio-control	Early Tran	6	2.1
Green Ash Draw	Infested	Late Tran	9	2.6
Green Ash Draw	Non-infested	Late Tran	4	5.4
Green Ash Draw	Bio-control	Late Tran	9	2.5
Green Ash Draw	Infested	Persistent	8	4.8
Green Ash Draw	Non-infested	Persistent	13	4.3
Green Ash Draw	Bio-control	Persistent	15	3.9
Green Ash Draw	Infested	Dormant	10	4.8
Green Ash Draw	Non-infested	Dormant	12	4.3
Green Ash Draw	Bio-control	Dormant	15	3.9
Green Ash Draw	Infested	Total SB	10	4.4
Green Ash Draw	Non-infested	Total SB	6	4.5
Green Ash Draw	Bio-control	Total SB	10	4.3

Table B-5.1 Kruskal Wallis one factor rank test results from seed bank species richness for non-infested, infested, and bio-control sites in green ash draw, needle-and-thread and silver sage vegetation types in the South Unit of Theodore Roosevelt National Park, ND.

Silver Sage Early Transient seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		4.99 (asymptotic $p = 0.08$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
5.4	Non-infested	$0.05 < p < 0.10$	$p > 0.20$
11.6	Infested		$p > 0.20$
9.1	Bio-control		
Silver Sage Late Transient seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		0.81 (asymptotic $p = 0.66$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
8.1	Non-infested	$p > 0.20$	$p > 0.20$
9.8	Infested		$p > 0.20$
7.4	Bio-control		
Silver Sage Persistent seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		4.23 (asymptotic $p = 0.12$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
9.8	Non-infested	$p > 0.20$	$p > 0.20$
11.6	Infested		$0.025 < p < 0.05$
5.8	Bio-control		
Silver Sage Late Dormant seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		1.25 (asymptotic $p = 0.54$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
10.2	Non-infested	$p > 0.20$	$p > 0.20$
7	Infested		$p > 0.20$
8.6	Bio-control		
Silver Sage Late Total seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		3.3 (asymptotic $p = 0.19$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
33.3	Non-infested	$p > 0.20$	$p > 0.20$
38.7	Infested		$0.10 < p < 0.20$
28.5	Bio-control		

Table B-5.1 continued

Needle-and-thread Early Transient seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		0.51 (asymptotic $p = 0.78$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
6.3	Non-infested	$p > 0.20$	$p > 0.20$
8.0	Infested		$p > 0.20$
8.0	Bio-control		
Needle-and-thread Late Transient seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		7.79 (asymptotic $p = 0.02$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
4.6	Non-infested	$0.1 < p < 0.20$	$0.01 < p < 0.025$
12.3	Infested		$p > 0.20$
11.7	Bio-control		
Needle-and-thread Persistent seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		2.96 (asymptotic $p = 0.23$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
6.6	Non-infested	$p > 0.20$	$0.10 < p < 0.20$
10.3	Infested		$p > 0.20$
11.7	Bio-control		
Needle-and-thread Dormant seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		3.28 (asymptotic $p = 0.19$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
6.4	Non-infested	$p > 0.20$	$p > 0.20$
10.3	Infested		$p > 0.20$
11.8	Bio-control		
Needle-and-thread Total seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		9.34 (asymptotic $p = 0.01$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
24.0	Non-infested	$0.025 < p < 0.05$	$0.01 < p < 0.025$
39.0	Infested		$p > 0.20$
40.0	Bio-control		

Table. B-5.1 continued

Green Ash Draw Early Transient seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		8.78 (asymptotic $p = 0.01$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
11.7	Non-infested	$0.01 < p < 0.025$	$p > 0.20$
3.4	Infested		$0.025 < p < 0.05$
10.1	Bio-control		
Green Ash Draw Late Transient seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		1.98 (asymptotic $p = 0.37$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
8.6	Non-infested	$p > 0.20$	$p > 0.20$
5.9	Infested		$p > 0.20$
10.2	Bio-control		
Green Ash Draw Persistent seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		12.5 (asymptotic $p = 0.002$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
3.5	Non-infested	$0.01 < p < 0.025$	$0.005 < p < 0.01$
10.0	Infested		$p > 0.20$
12.5	Bio-control		
Green Ash Draw Dormant seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		2.97 (asymptotic $p = 0.227$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
7.7	Non-infested	$p > 0.20$	$p > 0.20$
6.0	Infested		$p > 0.20$
11.0	Bio-control		
Green Ash Draw Total seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		9.68 (asymptotic $p = 0.008$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
34.8	Non-infested	$0.025 < p < 0.05$	$p > 0.20$
20.8	Infested		$0.01 < p < 0.025$
38.6	Bio-control		

Table B-6. Mean species richness for non-infested, infested and bio-control sites in green ash draw, needle-and-thread and silver sage vegetation types in the South Unit of Theodore Roosevelt National Park ND.

Vegetation Association	Composition	Mean species richness and standard deviations (Std dev)					
		-----Infested-----		-----Bio-control-----		-----Non-infested-----	
		species	Std dev	species	Std dev	species	Std dev
Silver sage	Forbs	13	2.8	10	3.9	13	8.5
Silver sage	Grass	4	2.3	5	4.4	3	1.7
Silver sage	Shrub	0	0.0	0	0.0	0	0.0
Silver sage	Tree	0	0.0	0	0.0	0	0.0
Silver sage	Vine	0	0.0	0	0.0	0	0.0
Silver sage	Non-native Forb	3	1.7	2	1.6	4	2.3
Silver sage	Non-native Grass	2	1.3	1	0.4	2	1.1
Needle-and-thread	Forbs	11	2.7	13	3.2	10	5.5
Needle-and-thread	Grasses	6	2.6	6	1.5	4	2.5
Needle-and-thread	Shrub	0	0.0	0	0.0	0	0.0
Needle-and-thread	Tree	0	0.3	0	0.0	0	0.2
Needle-and-thread	Vine	0	0.0	0	0.0	0	0.0
Needle-and-thread	Non-native Forb	4	2.1	5	2.2	2	1.2
Needle-and-thread	Non-native Grass	1	0.6	1	0.5	0	0.0
Green Ash Draw	Forbs	12	5.9	17	4.7	16	4.4
Green Ash Draw	Grasses	4	1.9	5	2.3	4	1.9
Green Ash Draw	Shrub	0	0.5	0	0.0	0	0.0
Green Ash Draw	Tree	1	0.5	1	0.4	1	0.0
Green Ash Draw	Vine	0	0.5	0	0.0	0	0.0
Green Ash Draw	Non-native Forb	2	0.5	4	0.6	4	1.0
Green Ash Draw	Non-native Grass	3	0.0	4	1.3	4	1.9

Table B-6.1. Kruskal Wallis One factor rank test results from seed bank species composition for forbs, grasses, shrubs, trees, vines, non-native forbs, and non-native grasses in leafy spurge infested, infested, with bio-control treatments and non-infested sites in silver sage, needle-and-thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND.

Silver Sage-Forbs			
Kruskal-Wallis statistic (adjusted for ties) testing		1.47 (asymptotic p = 0.480).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
7.4	Bio-control	p > 0.20	p > 0.20
11.	Infested		p > 0.20
10.1	Non-infested		
Silver Sage-Grass			
Kruskal-Wallis statistic (adjusted for ties) testing		2.21 (asymptotic p = 0.332).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
11	Bio-control	p > 0.20	p > 0.20
10.6.	Infested		p > 0.20
6.9	Non-infested		

Table B-6.1 continued

Silver Sage Non-native-Forbs			
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Kruskal-Wallis statistic (adjusted for ties) testing		2.09 (asymptotic $p = 0.352$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
7.2	Bio-control	$p > 0.20$	$p > 0.20$
9.8	Infested		$p > 0.20$
11.5	Non-infested		

Silver Sage Non-native-Grass

Kruskal-Wallis statistic (adjusted for ties) testing		2.66 (asymptotic $p = 0.265$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
7	Bio-control	$p > 0.20$	$p > 0.20$
11	Infested		$p > 0.20$
10.5	Non-infested		

Needle-and-thread-Forbs

Kruskal-Wallis statistic (adjusted for ties) testing		3.82 (asymptotic $p = 0.148$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
12.8	Bio-control	$p > 0.20$	$p > 0.20$
8.9	Infested		$p > 0.20$
6.8	Non-infested		

Needle-and-thread-Grass

Kruskal-Wallis statistic (adjusted for ties) testing		2.78 (asymptotic $p = 0.254$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
11	Bio-control	$p > 0.20$	$p > 0.20$
10.9	Infested		$p > 0.20$
6.8	Non-infested		

Needle-and-thread Non-native-Forbs

Kruskal-Wallis statistic (adjusted for ties) testing		3.98 (asymptotic $p = 0.137$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
11.5	Bio-control	$p > 0.20$	$p > 0.20$
11	Infested		$p > 0.20$
6	Non-infested		

Table B-6.1 continued

Needle-and-thread Non-native-Grass

Kruskal-Wallis statistic (adjusted for ties) testing		5.74 (asymptotic $p = 0.057$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
12	Bio-control	$p > 0.20$	$0.025 < p < 0.05$
10.5	Infested		$0.10 < p < 0.20$
6	Non-infested		

Green Ash Draw-Forbs

Kruskal-Wallis statistic (adjusted for ties) testing		2.85 (asymptotic $p = 0.241$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Non-Infested	Infested
10.1	Bio-control	$p > 0.20$	$p > 0.20$
9.2	Non-Infested		$p > 0.20$
5.1	Infested		

Green Ash Draw-Grass

Kruskal-Wallis statistic (adjusted for ties) testing		1.06 (asymptotic $p = 0.588$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Non-Infested	Infested
10	Bio-control	$p > 0.20$	$p > 0.20$
7.3	Non-Infested		$p > 0.20$
8.1	Infested		

Green Ash Draw Non-native-Forbs

Kruskal-Wallis statistic (adjusted for ties) testing		1.63 (asymptotic $p = 0.442$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Non-Infested	Infested
9.2	Bio-control	$p > 0.20$	$p > 0.20$
8.9	Non-Infested		$p > 0.20$
6.8	Infested		

Green Ash Draw Non-native-Grass

Kruskal-Wallis statistic (adjusted for ties) testing		8.18 (asymptotic $p = 0.017$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Non-Infested	Infested
10	Bio-control	$p > 0.20$	$0.01 < p < 0.025$
10.8	Non-Infested		$0.05 < p < 0.10$
2.9	Infested		

Table B-6.1 continued

Green Ash Draw-Trees

Kruskal-Wallis statistic (adjusted for ties) testing		1.43 (asymptotic $p = 0.49$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Non-Infested	Infested
8.2	Bio-control	$p > 0.20$	$p > 0.20$
9.5	Non-Infested		
7.5	Infested		

Green Ash draw Shrubs and Vines unable to calculate, too few occurrences

Table B-7. Leafy spurge mean seed bank density for non-infested, infested and bio-control sites in silver sage, needle-and-thread and green ash draw vegetation types in the South Unit of Theodore Roosevelt National Park, ND.

Vegetation type	Treatment	Seed bank	Density (seed/m ²)	Std dev
Silver sage	Bio-control	Transient	401.2	463.30
Silver sage	Infested	Transient	440.0	498.30
Silver sage	Non-infested	Transient	0.7	1.80
Silver sage	Bio-control	Persistent	357.2	454.70
Silver sage	Infested	Persistent	532.4	565.70
Silver sage	Non-infested	Persistent	6.7	16.40
Silver sage	Bio-control	Dormant	1.2	6.90
Silver sage	Infested	Dormant	8.2	15.90
Silver sage	Non-infested	Dormant	0.0	0.00
Silver sage	Bio-control	Total SB	762.9	886.26
Silver sage	Infested	Total SB	980.6	1057.20
Silver sage	Non-infested	Total SB	7.5	18.29
Needle-and-thread	Bio-control	Transient	3.7	15.41
Needle-and-thread	Infested	Transient	30.5	144.23
Needle-and-thread	Non-infested	Transient	0.0	0.00
Needle-and-thread	Bio-control	Persistent	33.7	154.31
Needle-and-thread	Infested	Persistent	61.8	185.66
Needle-and-thread	Non-infested	Persistent	0.0	0.00
Needle-and-thread	Bio-control	Dormant	5.2	9.13
Needle-and-thread	Infested	Dormant	58.2	115.2
Needle-and-thread	Non-infested	Dormant	0.0	0.00
Needle-and-thread	Bio-control	Total SB	95.5	99.27
Needle-and-thread	Infested	Total SB	296.0	195.56
Needle-and-thread	Non-infested	Total SB	0.0	0.00
Green Ash Draw	Bio-control	Transient	17.2	26.61
Green Ash Draw	Infested	Transient	160.0	177.94
Green Ash Draw	Non-infested	Transient	17.2	31.56
Green Ash Draw	Bio-control	Persistent	305.7	458.48
Green Ash Draw	Infested	Persistent	1127.5	1011.74
Green Ash Draw	Non-infested	Persistent	1.5	2.31
Green Ash Draw	Bio-control	Dormant	3.7	9.13
Green Ash Draw	Infested	Dormant	2.2	2.58
Green Ash Draw	Non-infested	Dormant	0.0	0.00
Green Ash Draw	Bio-control	Total SB	268.4	484.32
Green Ash Draw	Infested	Total SB	192.4	201.79
Green Ash Draw	Non-infested	Total SB	17.2	33.65

Table B-7.1. Kruskal Wallis test results from leafy spurge seed bank density for non-infested, infested, and bio-control sites in green ash draw, needle-and-thread and silver sage vegetation types in the South Unit of Theodore Roosevelt National Park, ND.

Silver Sage Transient seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		7.83 (asymptotic $p = 0.020$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
11.8	Bio-control	$p > 0.20$	$0.025 < p < 0.05$
12	Infested		$0.025 < p < 0.05$
4.7	Non-infested		
Silver Sage Persistent seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		9.5 (asymptotic $p = 0.009$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
4.3	Non-infested	$0.005 < p < 0.01$	$0.05 < p < 0.10$
13.2	Infested		$p > 0.20$
11.1	Bio-control		
Silver Sage Dormant seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		4.1 (asymptotic $p = 0.129$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
6.5	Non-infested	$0.10 < p < 0.20$	$0.10 < p < 0.20$
11.1	Infested		$p > 0.20$
10.9	Bio-control		
Silver Sage Total seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		9.89 (asymptotic $p = 0.007$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
11.4	Bio-control	$p > 0.20$	$0.025 < p < 0.05$
13	Infested		$0.005 < p < 0.01$
4.1	Non-infested		

Table B-7.1 continued

Needle-and-thread Transient seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		7. (asymptotic $p = 0.030$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.2	Bio-control	$p > 0.20$	$0.05 < p < 0.01$
12.8	Infested		$0.05 < p < 0.01$
5.5	Non-infested		
Needle-and-thread Persistent seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		11.39 (asymptotic $p = 0.01$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
4	Non-infested	$0.005 < p < 0.01$	$0.01 < p < 0.025$
13.9	Infested		$p > 0.20$
10.6	Bio-control		
Needle-and-thread Dormant seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		5.54 (asymptotic $p = 0.063$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
6.5	Non-infested	$0.05 < p < 0.10$	$p > 0.20$
12.6	Infested		$p > 0.20$
9.4	Bio-control		
Needle-and-thread Total seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		10.49 (asymptotic $p = 0.01$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10	Bio-control	$p > 0.20$	$0.25 < p < 0.05$
14	Infested		$0.005 < p < 0.01$
4.5	Non-infested		
Green Ash Draw Transient seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		6.54 (asymptotic $p = 0.038$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
6.8	Bio-control	$0.05 < p < 0.10$	$p > 0.20$
13.6	Infested		$0.05 < p < 0.10$
6.8	Non-infested		

Table B-7.1 continued

Green Ash Draw Persistent seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		9.5 (asymptotic $p = 0.009$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
4.3	Non-infested	$0.01 < p < 0.025$	$0.05 < p < 0.10$
13.2	Infested		$p > 0.20$
9.3	Bio-control		
Green Ash Draw Dormant seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		3.21 (asymptotic $p = 0.20$).	
testing Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Bio-control
7	Non-infested	$0.10 < p < 0.20$	$p > 0.20$
10.8	Infested		$p > 0.20$
8.5	Bio-control		
Green Ash Draw Total seed bank			
Kruskal-Wallis statistic (adjusted for ties) testing		9.89 (asymptotic $p = 0.007$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.3	Bio-control	$p > 0.20$	$p > 0.20$
11.3	Infested		$0.10 < p < 0.20$
5.8	Non-infested		

Table B-8. Mean seed density (seed/m²) of non-native species documented in the leafy spurge infested, leafy spurge infested with bio-control treatments and non-infested sites in silver sage, needle-and-thread and green ash draw vegetation associations in the South Unit of Theodore Roosevelt National Park, ND. (n = 6 for all sites except green ash draw infested sites where n = 4). Seed densities reported are sums of seed documented in transient, persistent and dormant seed bank fractions. Non-native species were determined by Northern Great Plains Floristic Quality Assessment Panel (2001).

Species	Silver sage*					
	Infested		Bio-control		Non-infested	
	Seed/m ²	Std dev	Seed/m ²	Std dev	Seed/m ²	Std dev
<i>Articum minus</i>	4a*	8.7	0a	0.0	1a	1.7
<i>Bromus inermis</i>	34a	58.2	1a	1.7	6a	11.9
<i>Bromus japonicus</i>	135a	250.1	0a	0.0	40a	83.1
<i>Bromus tectorum</i>	0a	0.0	5a	12.1	0a	0.0
<i>Camelina microcarpa</i>	0a	0.0	24a	58.9	14a	34.7
<i>Descuriana pinnata</i>	13a	13.3	35a	41.1	33a	43.7
<i>Euphorbia esula</i>	931a	10003.3	724a	847.1	7b	17.3
<i>Hyoscyamus niger</i>	0a	0.0	0a	0.0	1a	1.7
<i>Lactuca serrriola</i>	1a	2.2	3a	5.1	3a	6.9
<i>Lepidium densiflorum</i>	0a	0.0	0a	0.0	1a	1.7
<i>Linum perenne</i>	0a	0.0	3a	3.5	18a	45.1
<i>Lthospermum arvense</i>	0a	0.0	0a	0.0	1a	1.7
<i>Melilotus officinalis</i>	505a	258.3	938a	1244.9	931a	1754.9
<i>Poa annua</i>	1a	1.7	2a	5.2	0a	0.0
<i>Poa canbyi</i>	1a	1.7	0a	0.0	0a	0.0
<i>Poa compressa</i>	1a	3.5	0a	0.0	0a	0.0
<i>Poa pratensis</i>	68a	56.5	29a	28.5	101a	121.9
<i>Polygonum convolvulus</i>	11a	22.1	0a	0.0	6a	8.4
<i>Sonchus arvensis</i>	1a	1.7	0a	0.0	0a	0.0
<i>Taraxacum officinale</i>	7a	8.4	4a	8.7	11a	19.7
<i>Thlpsi arvense</i>	0a	0.0	0a	0.0	13a	31.2
<i>Tragopogon dubius</i>	2a	3.6	2a	3.6	1a	1.7

Species	Needle-and-thread*					
	Infested		Bio-control		Non-infested	
	Seed/m ²	Std dev	Seed/m ²	Std dev	Seed/m ²	Std dev
<i>Articum minus</i>	0a	0.0	30a	48.7	2a	5.2
<i>Bromus inermis</i>	1a	1.7	1a	2.2	0a	0.0
<i>Bromus japonicus</i>	3a	5.1	1a	2.2	0a	0.0
<i>Camelina microcarpa</i>	1a	3.5	1a	1.7	0	0.0
<i>Descuriana pinnata</i>	16a	18.2	17a	29.8	3a	5.1
<i>Euphorbia esula</i>	447a	321.1	164a	165.8	0a	0.0
<i>Lactuca serrriola</i>	15a	17.8	6a	6.9	4a	6.6
<i>Lappula squarrosa</i>	0a	0.0	0a	0.0	1a	1.7
<i>Lepidium latifolium</i>	1a	3.5	1a	1.7	0a	0.0
<i>Linum perenne</i>	0a	0.0	1a	3.5	1a	3.5
<i>Melilotus officinalis</i>	1a	2.2	11a	23.9	190a	462.2
<i>Poa pratensis</i>	4a	6.8	37a	57.0	4a	6.8
<i>Polygonum convolvulus</i>	0a	0.0	1a	1.7	0a	0.0
<i>Taraxacum officinale</i>	9a	14.2	12a	17.3	6a	8.8

Table B-8 continued

<i>Thlapsi arvense</i>	17a	37.1	2a	3.6	6a	11.9
<i>Tragopogon dubius</i>	17a	13.4	7a	5.8	6a	11.9

Species	Green ash draw*					
	Infested		Bio-control		Non-infested	
	Seed/m ²	Std dev	Seed/m ²	Std dev	Seed/m ²	Std dev
<i>Articum minus</i>	3b	6.4	34ab	54.3	105a	181.9
<i>Bromus inermis</i>	3b	6.4	36ab	86.7	1b	3.5
<i>Bromus japonicus</i>	0a	0.0	13a	31.2	52a	128.3
<i>Camelina microcarpa</i>	0a	0.0	0a	0.0	1a	2.2
<i>Descuriana pinnata</i>	2a	2.5	0a	0.0	3a	3.5
<i>Euphorbia esula</i>	822a	1163.6	310ab	446.9	18b	31.3
<i>Lactuca serrriola</i>	3b	6.4	17a	9.7	8ab	5.6
<i>Lappula squarrosa</i>	0a	0.0	9a	10.7	6a	10.7
<i>Linum perenne</i>	0a	0.0	3a	5.1	0a	0.0
<i>Melilotus officinalis</i>	37a	41.2	61a	98.1	18a	23.9
<i>Poa annua</i>	2a	4.3	28a	49.4	5a	12.1
<i>Poa compressa</i>	47a	82.5	6a	8.8	12a	25.6
<i>Poa pratensis</i>	22a	15.3	390a	668.9	39a	40.4
<i>Polygonum convolvulus</i>	0a	0.0	1a	2.2	11a	13.6
<i>Salsola iberica</i>	0a	0.0	0a	0.0	2a	5.2
<i>Setaria veridis</i>	0a	0.0	0a	0.0	1a	1.7
<i>Silene antirrhina</i>	0a	0.0	0a	0.0	9a	20.8
<i>Taraxacum officinale</i>	7a	14.9	19a	12.8	27a	21.1
<i>Tragopogon dubius</i>	3a	4.1	4a	4.7	0a	0.0

* Letters in common within a row denote no significant differences detected at $p \geq 0.05$ using the Kruskal Wallis test.

Table B-8.1. Kruskal Wallis One factor rank test results from seed bank species richness for non-infested, infested, and bio-control sites in green ash draw, needle-and-thread and silver sage vegetation types in Theodore Roosevelt National Park. The first three letters represent the first three letters of the genus species name.

Arc min- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		1.07 (asymptotic $p = 0.586$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
8.5	Bio-control	$p > 0.20$	$p > 0.20$
10.1	Infested		$p > 0.20$
9.9	Non-infested		

Table B-8.1 continued

Bro ine- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		2.32 (asymptotic $p = 0.313$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
7.7	Bio-control	$p > 0.20$	$p > 0.20$
11.6	Infested		$p > 0.20$
9.3	Non-infested		
Bro jap- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		4.14 (asymptotic $p = 0.126$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
6.5	Bio-control	$0.10 < p < 0.20$	$0.10 < p < 0.20$
11.4	Infested		$p > 0.20$
10.6	Non-infested		
Cam mic- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		1.07 (asymptotic $p = 0.586$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.1	Bio-control		Not enough data to test
8.5	Infested		
9.9	Non-infested		
Des pin- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		0.39 (asymptotic $p = 0.822$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.2	Bio-control	$p > .20$	$p > .20$
8.4	Infested		$p > .20$
9.9	Non-infested		
Eup esu- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		9.99 (asymptotic $p = 0.007$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
11.4	Bio-control	$p > .20$	$0.025 < p < 0.05$
13.0	Infested		$0.005 < p < 0.01$
4.1	Non-infested		

Table B-8.1 continued

Hyo nig- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		2.0 (asymptotic $p = 0.386$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.0	Bio-control		Insufficient data to test
9.0	Infested		
10.0	Non-infested		
Lac ser- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		0.25 (asymptotic $p = 0.885$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.0	Bio-control	$p > 0.20$	$p > 0.20$
9.7	Infested		$p > 0.20$
8.8	Non-infested		
Lep lat- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		2.0 (asymptotic $p = 0.368$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.0	Bio-control		Insufficient data to test
9.0	Infested		
10.5	Non-infested		
Lin per- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		3.86 (asymptotic $p = 0.163$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
11.8	Bio-control	$0.10 < p < 0.20$	$p > 0.20$
7.5	Infested		$p > 0.20$
9.3	Non-infested		
Lit arv- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		2.0 (asymptotic $p = 0.365$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.0	Bio-control	Unable to test	
9.0	Infested		
10.5	Non-infested		

Table B-8.1 continued

Mel off- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		0.76 (asymptotic $p = 0.684$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.7	Bio-control	$p > 0.20$	$p > 0.20$
10.8	Infested		$p > 0.20$
8.1	Non-infested		
Poa ann- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		1.07 (asymptotic $p = 0.586$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.1	Bio-control	$p > 0.20$	$p > 0.20$
9.9	Infested		$p > 0.20$
8.5	Non-infested		
Poa pra Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		3.63 (asymptotic $p = 0.16$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
6.2	Bio-control	$p > 0.20$	$0.10 < p < 0.20$
10.7	Infested		$p > 0.20$
11.7	Non-infested		
Pol con- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		3.34 (asymptotic $p = 0.167$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
7.0	Bio-control	$p > 0.20$	$0.10 < p < 0.20$
10.3	Infested		$p > 0.20$
11.3	Non-infested		
Son arv Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		2.0 (asymptotic $p = 0.368$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.0	Bio-control	$p > 0.20$	$p > 0.20$
10.5	Infested		$p > 0.20$
9.0	Non-infested		

Table B-8.1 continued

Tar off- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		2.59 (asymptotic $p = 0.273$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
6.8	Bio-control	$p > 0.20$	$p > 0.20$
10.8	Infested		$p > 0.20$
10.8	Non-infested		
Thl arv- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		0.2.00 (asymptotic $p = 0.37$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.0	Bio-control		Insufficient data to test
9.0	Infested		
10.5	Non-infested		
Tra tub- Silver sage			
Kruskal-Wallis statistic (adjusted for ties) testing		0.69 (asymptotic $p = 0.707$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.1	Bio-control	$p > 0.20$	$p > 0.20$
10.1	Infested		$p > 0.20$
8.3	Non-infested		
Arc min- Needle-and-thread			
Kruskal-Wallis statistic (adjusted for ties) testing		2.52 (asymptotic $p = 0.283$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
11.2	Bio-control	$p > 0.20$	$p > 0.20$
8.0	Infested		$p > 0.20$
9.3	Non-infested		
Bro ine- Needle-and-thread			
Kruskal-Wallis statistic (adjusted for ties) testing		2.27 (asymptotic $p = 0.322$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
11.0	Bio-control	$p > 0.20$	$p > 0.20$
9.5	Infested		$p > 0.20$
8.0	Non-infested		

Table B-8.1 continued

Bro jap- Needle-and-thread			
Kruskal-Wallis statistic (adjusted for ties) testing		2.42 (asymptotic $p = 0.298$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.3	Bio-control	$p > 0.20$	$p > 0.20$
10.7	Infested		$p > 0.20$
7.5	Non-infested		
Cam mic- Needle-and-thread			
Kruskal-Wallis statistic (adjusted for ties) testing		1.07 (asymptotic $p = 0.568$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.9	Bio-control	$p > 0.20$	$p > 0.20$
10.1	Infested		$p > 0.20$
8.5	Non-infested		
Des pin- Needle-and-thread			
Kruskal-Wallis statistic (adjusted for ties) testing		2.25 (asymptotic $p = 0.324$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.3	Bio-control	$p > .20$	$p > .20$
11.2	Infested		$p > .20$
7.0	Non-infested		
Eup esu- Needle-and-thread			
Kruskal-Wallis statistic (adjusted for ties) testing		11.94 (asymptotic $p = 0.003$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.3	Bio-control	$p > .20$	$0.01 < p < 0.025$
14.3	Infested		$0.005 < p < 0.01$
4.0	Non-infested		
Lac ser-Needle and Thread			
Kruskal-Wallis statistic (adjusted for ties) testing		1.4 (asymptotic $p = 0.497$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.3	Bio-control	$p > 0.20$	$p > 0.20$
11.3	Infested		$p > 0.20$
8.0	Non-infested		

Table B-8.1 continued

<u>Lep squ- Needle and Thread</u>			
Kruskal-Wallis statistic (adjusted for ties) testing		1.07 (asymptotic $p = 0.568$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.9	Bio-control	$p > 0.20$	$p > 0.20$
10.1	Infested		$p > 0.20$
8.5	Non-infested		
<u>Lep lat- Needle-and-thread</u>			
Kruskal-Wallis statistic (adjusted for ties) testing		1.07 (asymptotic $p = 0.568$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.9	Bio-control	$p > 0.20$	$p > 0.20$
10.1	Infested		$p > 0.20$
8.5	Non-infested		
<u>Lin per- Needle-and-thread</u>			
Kruskal-Wallis statistic (adjusted for ties) testing		1.06 (asymptotic $p = 0.568$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.0	Bio-control	$p > 0.20$	$p > 0.20$
8.5	Infested		$p > 0.20$
10.0	Non-infested		
<u>Mel off- Needle-and-thread</u>			
Kruskal-Wallis statistic (adjusted for ties) testing		0.15 (asymptotic $p = 0.928$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.5	Bio-control	$p > 0.20$	$p > 0.20$
9.0	Infested		$p > 0.20$
10.0	Non-infested		
<u>Poa pra- Needle-and-thread</u>			
Kruskal-Wallis statistic (adjusted for ties) testing		1.14 (asymptotic $p = 0.56$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
11.2	Bio-control	$p > 0.20$	$p > 0.20$
8.7	Infested		$p > 0.20$
8.7	Non-infested		

Table B-8.1 continued

<u>Pol con- Needle-and-thread</u>			
Kruskal-Wallis statistic (adjusted for ties) testing		2.0 (asymptotic $p = 0.368$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.5	Bio-control	$p > 0.20$	$p > 0.20$
9.0	Infested		$p > 0.20$
9.0	Non-infested		
<u>Tar off- Needle-and-thread</u>			
Kruskal-Wallis statistic (adjusted for ties) testing		1.1 (asymptotic $p = 0.576$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
11.3	Bio-control	$p > 0.20$	$p > 0.20$
8.3	Infested		$p > 0.20$
8.9	Non-infested		
<u>Tra dub-Needle-and-thread</u>			
Kruskal-Wallis statistic (adjusted for ties) testing		2.46 (asymptotic $p = 0.292$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.7	Bio-control	$p > 0.20$	$p > 0.20$
11.8	Infested		$p > 0.20$
7.1	Non-infested		
<u>Thl arv- Needle and Thread</u>			
Kruskal-Wallis statistic (adjusted for ties) testing		0.75 (asymptotic $p = 0.689$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
8.7	Bio-control	$p > 0.20$	$p > 0.20$
10.8	Infested		$p > 0.20$
9.0	Non-infested		
<u>Arc min- Green Ash Draw</u>			
Kruskal-Wallis statistic (adjusted for ties) testing		4.19 (asymptotic $p = 0.123$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
8.4	Bio-control	$p > 0.20$	$p > 0.20$
4.9	Infested		$p > 0.20$
11.0	Non-infested		

Table B-8.1 continued

Bro ine- Green Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		4.19 (asymptotic $p = 0.123$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
8.4	Bio-control	$p > 0.20$	$p > 0.20$
4.9	Infested		$p > 0.20$
11.0	Non-infested		
Bro jap- Green Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		0.16 (asymptotic $p = 0.924$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
8.5	Bio-control	$p > 0.20$	$p > 0.20$
9.0	Infested		$p > 0.20$
8.2	Non-infested		
Cam mic- Green Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		3.57 (asymptotic $p = 0.168$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
7.5	Bio-control		Not enough data to test
7.5	Infested		
10.2	Non-infested		
Des pin- Green Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		4.03 (asymptotic $p = 0.133$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
6.0	Bio-control	$.10 < p < 0.20$	$0.10 < p < 0.20$
9.8	Infested		$p > .20$
10.2	Non-infested		
Eup esu- Green Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		5.75 (asymptotic $p = 0.056$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.1	Bio-control	$p > .20$	$p > .20$
12.5	Infested		$0.025 < p < 0.05$
5.3	Non-infested		

Table B-8.1 continued

Lac ser- Green Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		6.49 (asymptotic $p = 0.39$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
12.0	Bio-control	$0.05 < p < 0.10$	$0.10 < p < 0.20$
4.5	Infested		$p > 0.20$
7.7	Non-infested		
Lap squ- Green Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		2.45 (asymptotic $p = 0.294$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.9	Bio-control	$p > 0.20$	$p > 0.20$
6.0	Infested		$p > 0.20$
8.8	Non-infested		
Lin per- Green Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		3.5 (asymptotic $p = 0.169$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.2	Bio-control	$p > 0.20$	$p > 0.20$
7.5	Infested		$p > 0.20$
7.5	Non-infested		
Mel off- Green Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		1.01 (asymptotic $p = 0.605$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
9.4	Bio-control	$p > 0.20$	$p > 0.20$
9.4	Infested		$p > 0.20$
7.0	Non-infested		
Poa ann- Green Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		3.27 (asymptotic $p = 0.195$).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.9	Bio-control	$p > 0.20$	$p > 0.20$
7.0	Infested		$p > 0.20$
7.1	Non-infested		

Table B-8.1 continued

Poa com- Green Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		.56 (asymptotic p = 0.757).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
8.5	Bio-control	p > 0.20	p > 0.20
9.8	Infested		p > 0.20
7.7	Non-infested		
Poa praGreen Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		2.02(asymptotic p = 0.364).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.6	Bio-control	p > 0.20	p > 0.20
6.5	Infested		p > 0.20
7.8	Non-infested		
Pol con- Green Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		3.25 (asymptotic p = 0.197).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
8.2	Bio-control	p > 0.20	p > 0.20
6.0	Infested		p > 0.20
10.5	Non-infested		
Sil ant Green Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		(asymptotic p = 0.)	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
	Bio-control		In sufficient data to test
	Infested		
	Non-infested		
Tar off- Green Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		3.65 (asymptotic p = 0.161).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
8.8	Bio-control	p > 0.20	p > 0.20
4.9	Infested		0.10 < p < 0.20
10.7	Non-infested		

Table B-8.1 continued

Tra dub- Green Ash Draw			
Kruskal-Wallis statistic (adjusted for ties) testing		4.06 (asymptotic p = 0.131).	
Ho: group effects are equal.			
Multiple comparisons based on pairwise two sample rankings.		Approximate experimentwise significance levels for Ho: two group effect are equal.	
Mean Rank	Group	Infested	Non-infested
10.3	Bio-control	p > 0.20	p > 0.20
9.6	Infested		p > 0.20
6.0	Non-infested		