The influence of prescribed burning and grazing on the Dakota Skipper, *Hesperia dacotae*, habitat in south-eastern Manitoba.

Lara Michelle Bates

Supervisor: Dr. A.R. Westwood

A thesis submitted in partial fulfillment of the Honours Thesis (BIOL 4111/6) Course

Department of Biology

The University of Winnipeg

2007

Abstract

The Dakota Skipper, *Hesperia dacotae* (Skinner), has been extirpated from the Tall Grass Prairie Preserve (TGPP) in south-eastern Manitoba and is considered threatened over its remaining distribution in Canada. Existing Manitoban populations are now confined to privately owned lands and it is important to re-establish populations in protected habitats, such as the TGPP. The TGPP is being assessed for the potential to support future introductions of the Dakota Skipper. It is thought that disturbances, such as unmanaged burning and cattle grazing, were the cause of the extirpation of the Dakota Skipper from this area. This study investigated the vegetative composition of three age groups of previously burned sites and one grazed site in the TGPP, as well as the butterfly species present. The plant diversity of the sites was examined to determine the incidence of Dakota Skipper larval host plants and adult nectar sources, including an assessment of species richness, Shannon's diversity and evenness, rank/abundance and rarefied species richness. The results indicated that more recently burned plots had higher plant diversity and evenness and a higher prevalence of larval and adult plant requirements, suggesting they are more suitable sites for reintroduction of the Dakota Skipper.

Acknowledgements

I would like to thank the following people for the assistance they provided in the completion of this project on the threatened butterfly, *Hesperia dacotae*, the Dakota Skipper. To my supervisor Dr. Richard Westwood, thank you for the knowledge, guidance, patience and friendship. To my committee members, Dr. Richard Staniforth and Bill Watkins from Manitoba Conservation, thank you for the support and encouragement, as well as the knowledge and expertise you provided. To Dr. Ric Moodie for organizing the course and keeping us informed and prepared. To Manitoba Conservation, the Natural Sciences and Engineering Research Council (NSERC) and the University of Winnipeg for the funding to complete my research. To the field assistants who endured the hot, sweaty hours of data collection: Alana Westwood, Amanda Dumont, Chris Friesen, David Christiansen, Garnet Bates, Lindsay Decock and Phyllis Bates. To the staff at the Tall Grass Prairie Preserve who answered numerous questions on plant identification: Christie Borkowski and Laura Reaves. Also to my family and friends, who supported me through the past year.

Table of Contents

Abstract ii

Acknowledgements iii

Table of Contents iv

List of Figures, Tables and Appendices v

Introduction 1
- Biology 1
- Manitoba's Tall-Grass Prairie 5
- Population Status of the Dakota Skipper 7
- Habitat Requirements 9
- The Tall-Grass Prairie Preserve 10
- Study Objective 12

Methods and Materials 13
- Study Area: The Tall Grass Prairie Preserve 13
- Experimental Procedures 14
  - Vegetation Surveys 16
  - Biomass Surveys 17
  - Butterfly Surveys 17
- Statistical Analysis 18
  - Diversity Indices 18
  - Shannon's Diversity Index 19
  - Shannon's Evenness 19
  - Rarefaction 20
  - Rank/Abundance 21
  - Cluster Analysis 22
  - Analysis of Variance (ANOVA) 23

Results 24

Discussion 35

Conclusions 40

References 41

Appendix A 45
Appendix B 46

List of Figures, Tables and Appendices

Figure 1: Dorsal (left) and ventral (right) wing surfaces of a male (top) and female (bottom) adult Dakota Skipper (COSEWIC, 2003). 4

Figure 2: Map of the Tall Grass Prairie Preserve (Manitoba Conservation, 2007). 14

Figure 3: Enlarged aerial photograph of the southern portion of the Tall Grass Prairie Preserve (Figure 2) showing the two replicates within each treatment type (Google Earth, 2005). 16

Figure 4: The rarefied species richness curves determined with EcoSim (Gotelli and Entsminger, 2005). 30

Figure 5: Jaccard's Cluster Analysis dendrogram of similarity coefficients for comparison between treatments using Systat (Systat, 2004b). 34

Table 1: The land section and GPS coordinates for the replicates of the four treatment types. 15

Table 2: List of ranked mean percent cover of vascular plant species found in burn year 1993 (Treatment 1)[1]. 25

Table 3: List of ranked mean percent cover of vascular plant species found in burn year 1998 (Treatment 2)[1]. 26

Table 4: List of ranked mean percent cover of vascular plant species found in burn year 1998 that included grazing (Treatment 3)[1]. 27

Table 5: List of ranked mean percent cover of vascular plant species found in burn year 2002 (Treatment 4)[1]. 28

Table 6: List of ranked mean percent cover of plants in flower found during the July sampling period for all treatments[1]. 29

Table 7: Comparison of mean diversity values: Species Richness, Shannon's Diversity, Shannon's Evenness, Rarefied Species Richness, and Rank/Abundance. 31

Table 8: Comparison of mean spring and fall biomass. 31

Table 9: Comparison of mean percent cover of larval host plants and adult nectar sources. 32

Table 10: Jaccard's Cluster Matrix of β diversity coefficients for comparison between treatments using Systat (Systat, 2004b). 33

Appendix A: The total species lists for the June/August and July sampling periods. 45

Appendix B: A catalog of the number of butterflies and date found for each survey. 46

Introduction

Biology

The Dakota Skipper, *Hesperia dacotae* (Skinner), is a member of the subfamily Hesperiinae (Branded Skippers) within the family Hesperidae (Skippers) in the Order Lepidoptera (COSEWIC, 2003). The Dakota Skipper is univoltine and undergoes complete metamorphosis (COSEWIC, 2003). The eggs are smooth surfaced and hemispherical in shape with a basal diameter of approximately 1.21 mm and height of approximately 0.95 mm (Dana, 1991; COSEWIC, 2003). Eggs appear gleaming, semi-translucent white, although the surface shine dulls several hours after oviposition (Dana, 1991). Embryogenesis varies depending upon the weather and lasts from seven to twenty days, at which time the larvae hatch and are about three mm in length (McCabe, 1981; Dana, 1991; Webster, 2003). The caterpillars (larvae) pass through six or seven instars before pupation occurs (COSEWIC, 2003). Larvae build shelters at or below the bases of grass stems by combining various plant materials and silk (Dana, 1991). These shelters are placed vertically within the soil and new shelters are reconstructed as the larvae grow (McCabe, 1981; Dana, 1991). Larval growth is generally slow and is interrupted by an obligatory winter diapause at the fourth or fifth instar stage, with the over-wintering shelter located approximately five mm underground (McCabe, 1981; Dana, 1991; COSEWIC, 2003; Webster, 2003). Following diapause, the larvae construct shelters horizontally on the soil surface using silk covered in a layer of soil and debris (Dana, 1991). The larvae continue to feed and grow through two more instars and then pupation occurs (Dana,

1991). Prior to pupation, the larvae construct a final shelter, which is impervious to water (Dana, 1991).

The larvae of the *H. dacotae* spend most of their time sheltered within the silken chamber, and only emerge nocturnally to feed on the host plants (McCabe, 1981; Dana, 1991; Webster, 2003). To feed, larvae cut off pieces of plant material and pull them back into the chamber (Dana, 1991). There have been several larval host plants documented, including Little Bluestem (*Andropogon scoparius* Michx.), Big Bluestem (*Andropogon gerardii* Vitman), Sideoats Grama (*Bouteloua curtipendula* Michx.) and Prairie Dropseed (*Sporobolus heterolepis* A. Grey), with secondary host plants being Kentucky Bluegrass (*Poa pratensis* L.) and Wilcox Dicanthelium (*Dichanthelium wilcoxianum* (Vasey) Freckmann) (McCabe, 1981; Dana, 1991; COSEWIC, 2003). The larvae tend to be oligophagus on grass species of virgin prairie habitats (McCabe, 1981; Dana, 1991; COSEWIC, 2003).

The larvae of *H. dacotae* have distinctive ventral pits on the head capsule (McCabe, 1981). The head, prothoracic shield, thoracic legs and spiracles are black and the rest of the body integument is minutely granular and light brown (McCabe, 1981; COSEWIC, 2003). A fully grown larva has a white patch on the venter of the 7th and 8th abdominal segments, which consists of a waxy hydrofuge substance (McCabe, 1981). This waxy substance is distributed over the integument when pupation occurs to protect the pupa from moisture in the environment (McCabe, 1981). Few larval predators or parasites have been documented, but larvae and pupa are both susceptible to death caused by bacterial septicaemia, which is associated with moisture (McCabe, 1981). The full-grown larva reaches a length of approximately 20 mm (COSEWIC, 2003).

The adults emerge over a three week period usually beginning mid to late June and ending in mid to late July, with males appearing an average of five days earlier than females (McCabe, 1981; Dana, 1991; Schlicht, 1997; Swengel and Swengel, 1999; COSEWIC, 2003). The flight period is determined by weather conditions in the spring season (McCabe, 1981). The adults are active diurnally and prominent behaviours include mate-seeking by males, oviposition by females and regular visits to flowers for feeding (Dana, 1991). The Dakota Skipper has been documented to utilize many nectar-producing plant species, including Black-eyed Susan (*Rudbeckia serotina* Nutt), Wood Lily (*Lilium philadelphicum* L.) and Harebell (*Campanula rotundifolia* L.) (McCabe, 1981; Dana, 1991). It appears that they prefer plants that have concealed nectar sources, but are opportunistic and will feed upon many species (McCabe, 1981; Dana, 1991). Nectar is critical for survival as a source of water and to a lesser extent carbohydrates, because the skippers fly about rapidly during the day when temperatures are high (Dana, 1991; Webster, 2003).

Mate-seeking involves perching behaviour, where males sit motionless upon vegetation, ready for flight if a butterfly passes (Dana, 1991). The male is not selective and will pursue many butterfly species, which often results in an aerial engagement between the two (Dana, 1991). When pursuit is with a conspecific female, she may descend into the vegetation and the male will follow to initiate copulation (Dana, 1991). Most copulation efforts are unsuccessful and multiple attempts are made by a male with a particular female (Dana, 1991). Females that have been successfully courted will oviposit eggs close to the soil surface, upon grass blades or on the underside of herbaceous leaves (McCabe, 1981; Dana, 1991; COSEWIC, 2003; Webster, 2003). Eggs are laid singly and a female can lay

20 to 30 per day with potential fecundity of 180 to 250 eggs over her life span (Dana, 1991; COSEWIC, 2003).

The adult wing span of *H. dacotae* ranges from 21 to 29 mm and the species shows sexual dimorphism (Figure 1) (COSEWIC, 2003). The upper wing surface of males is tawny orange with a diffuse brownish border and an elongated dark marking present, called a stigma, which consists of porous scales containing pheromones (Dana, 1991; COSEWIC, 2003). Males release pheromones to allow females to identify them (Dana, 1991). The underside is yellowish orange with faint whitish spots (COSEWIC, 2003). The female upper wing surface ranges in colour from buff to brown and has several small, whitish spots on the forewing (COSEWIC, 2003). The underside is yellowish-brown with faint whitish spots on the hind wing (COSEWIC, 2003). Individual wing pattern variation is common in both males and females (COSEWIC, 2003).

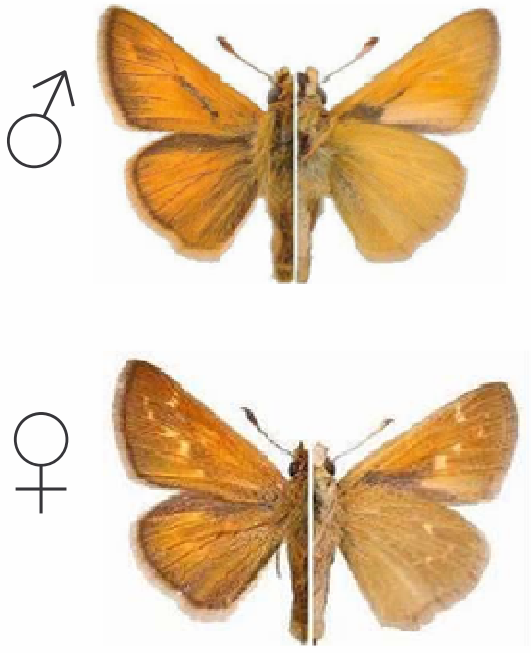

Figure 1: Dorsal (left) and ventral (right) wing surfaces of a male (top) and female (bottom) adult Dakota Skipper (COSEWIC, 2003).

Manitoba's Tall-Grass Prairie

Within Manitoba, the tall-grass prairie once stretched from present-day Winnipeg to the south-eastern limits of the province, covering approximately 6,000 km^2 (Joyce and Morgan, 1989; Manitoba Conservation, 2007). This was the northernmost extent of the North American tall-grass prairies and the largest expanse of tall-grass prairies found within Canadian borders (Joyce and Morgan, 1989). Today less than 1% of this biome remains in North America (Joyce and Morgan, 1989) and very little of these lands are protected (Samson and Knopf, 1997).

The prairie biomes were naturally moulded by the processes of fire (both natural and deliberately set by native North Americans), grazing by ungulates and insects, soil type, topography and periods of drought and freezing (McCabe, 1981; Gibson and Hulbert, 1987; Howe, 1994; Swengel, 1998; Manitoba Conservation, 2007). These natural processes have been interrupted because of widespread habitat fragmentation and destruction (Swengel, 1998). Fire is recognized as an important influence upon tall-grass prairies, as it helps to break down accumulating leaf litter, returning nutrients to the soil and allowing sunlight to thaw the soil in spring, and prevents fire-intolerant species of shrubs and trees from becoming established (Kucera and Koelling, 1964; McCabe, 1981; Gibson and Hulbert, 1987; Swengel, 1998; Manitoba Conservation, 2007). The historical seasonality and frequency of these fires is unclear, because no records exist prior to European colonization of the tall-grass prairie in North America (Swengel and Swengel, 2001). Native tall-grass plant species are tolerant of fire because of their extensive underground root systems, thus fires tend to favour native species of prairie plants, while suppressing exotic

and fire-intolerant species (Panzer, 2002; Manitoba Conservation, 2007). Prescribed burning has become common as a technique to preserve the natural flora of the tall-grass prairie ecosystem (Panzer and Schwartz, 2000).

Fire increases the productivity of the native grassland species, but if too intense or in the absence of other disturbances, it may be harmful to prairie-obligate species of plants, animals and invertebrates, especially rare species with limited dispersal (Swengel, 1996; Swengel, 1998; Swengel, 2001; Panzer, 2002). Fire initially reduces number of invertebrates due to death and emigration and continues to harm insects because of exposure and starvation (Swengel, 1996; Swengel, 2001). Fire has been found to reduce the number of herbaceous plant species in flower and increase the density of grass species, when the intervals are too frequent (Howe, 1994; Swengel, 1996; Swengel, 2001).

In pre-settlement conditions, grazing by ungulates occurred naturally in prairie ecosystems and provided a source of fertilizer and allowed for seed dispersal (Howe, 1994; Manitoba Conservation, 2007). The intensity of grazing by naturally occurring ungulates was considerably less than present day domesticated grazers (Howe, 1994; Swengel, 2001; COSEWIC, 2003). When areas are used for cattle grazing, they are vulnerable to overgrazing, which reduces nectar sources and larval plant food (Swengel, 2001; COSEWIC, 2003).

The tall-grass prairies in Manitoba are found amid aspen (*Populus spp.*) and bur oak (*Quercus macrocarpa* Michx.) groves that have alternating lower, wetter and higher, drier areas (Swengel, 1998; COSEWIC, 2003). The wetter areas are dominated by species such as Tufted Hair Grass (*Deschampsia caespitosa* (L.) Beauv.), Redtop (*Agrostis stolonifera* L.),

various sedges (*Carex spp.*) and rushes (*Juncus spp.*) and Mat Muhly (*Muhlenbergia richardsonis* (Trin.)) (COSEWIC, 2003). Shrubby Cinquefoil (*Pentaphylloides floribunda* (Pursh)), is found in more hydric sites (COSEWIC, 2003). Drier sites are dominated by bluestem grasses such as Little Bluestem (*A. scoparius*), Big Bluestem (*A. gerardii*), Prairie Dropseed (*S. heterolepis*), and various herbaceous species, such as Wood Lily (*L. philadelphicum*), Smooth Camas (*Zygadenus elegans* Pursh), Harebell (*C. rotundifolia*), and Black-eyed Susan (*R. serotina*) (COSEWIC, 2003).

Population Status of the Dakota Skipper

Historically, *H. dacotae* occupied part of the northern prairies within Illinois, Iowa and north to the Dakotas and southern Manitoba (Dana, 1991). The Dakota Skipper has been extirpated from most of the southern range and now only remains in isolated populations from southern Manitoba, south-eastern Saskatchewan, eastern North and South Dakota and western Minnesota (COSEWIC, 2003). Within Manitoba, there are 19 to 20 sites, in the inter-lake region between Lake Manitoba and Lake Winnipeg, where the Dakota Skipper is found (COSEWIC, 2003). *Hesperia dacotae* was last found in seven sites near Tolstoi, Gardenton and Stuartburn in 1987, but has since been extirpated from this area (COSEWIC, 2003; Morden, 2006). The Dakota Skipper is considered threatened in Canada and endangered in Manitoba, and has been placed under the Endangered Species Act (COSEWIC, 2003).

Population estimates of prairie skippers are made by visually surveying for adult butterflies and making approximations of the total population from the density of adults observed and the amount of suitable habitat (Webster, 2003). This method is crude and

the results should be viewed with caution (COSEWIC, 2003). The minimum viable population size needs to be determined and incorporated with population estimates to assist in categorizing the abundances of the Dakota Skipper (Schlicht, 1997; Environment Canada, 2007). The population declines of the Dakota Skipper are due to habitat destruction and loss (McCabe, 1981). The surviving populations are vulnerable to disturbances, such as cattle grazing, prescribed burning, agriculture, haying and succession (McCabe, 1981; COSEWIC, 2003; Webster, 2003). The adults and larvae are able to use a variety of plant species for food sources and reproduction but are restricted to plant species from undisturbed prairie habitats (COSEWIC, 2003). The plant species that are eliminated, during grazing by domesticated cattle, may be those that the adult and caterpillars depend upon heavily (Dana, 1991). The season of prescribed fire can greatly affect the survival of the Dakota Skipper, as each developmental stage is vulnerable to the effects at different times of the year (Swengel, 2001). When land is used for agriculture or left without any management intervention, floristic changes occur, which reduce important plant species required by prairie invertebrates (Swengel, 2001).

When the tall-grass prairie habitat was large and continuous, the Dakota Skipper re-colonized disturbed areas from populations in nearby undisturbed areas or migrated out of the burned or grazed habitat (McCabe, 1981). Today, the remaining habitats are small and fragmented, which does not allow the Dakota Skipper to survive or disperse back into a burned or grazed area (McCabe, 1981; Panzer, 2002). Although the Dakota Skipper is a strong flyer, it does not seem to fly far between isolated prairie habitats and is not likely to re-colonize an area where it has been extirpated, unless surviving populations are within a

kilometre (Dana, 1991; Swengel, 1998; Swengel, 2001; COSEWIC, 2003). Furthermore, the Dakota Skipper produces only one generation per year and recovery rates into disturbed areas occurs slowly (Swengel, 1996; Panzer and Schwartz, 2000; Panzer, 2002). The most beneficial management practices, for long term species survival, appear to be haying late in the season, as it appears healthy populations can exist under these circumstances (McCabe, 1981; Swengel, 1996; Swengel, 2001; COSEWIC, 2003). Late season haying increases the ratio of forbs to grasses and thus increases adult nectar sources (Swengel, 1996).

Habitat Requirements

Hesperia dacotae is an obligate inhabitant of mixed and tall-grass prairie biomes (COSEWIC, 2003). Within Manitoba, *H. dacotae* is associated with wet-to-mesic tall-grass prairie (COSEWIC, 2003). The Dakota Skipper has been found on sites with unproductive alkaline soils that range between a pH of 7.2 and 7.8 (McCabe, 1981). In the tall-grass prairie, bluestem grasses and abundant nectar sources are important for *H. dacotae* survival (COSEWIC, 2003). The Dakota Skipper is often found with the herbaceous plant Smooth Camus (*Z. elegans*) and their distributions are concurrent, although *H. dacotae* does not depend directly upon this plant as a nectar source or a larval host plant (McCabe, 1981; COSEWIC, 2003). Other indicator plants of Dakota Skipper habitat include Wood Lily (*L. philadelphicum*), Harebell (*C. rotundifolia*) and Black-eyed Susan (*R. serotina*) (COSEWIC, 2003).

Hesperia dacotae adults are seen most often utilizing Black-eyed Susan (*R. serotina*), Wood Lily (*L. philadelphicum*) and Harebell (*C. rotundifolia*) as nectar sources (COSEWIC,

2003). Females do not appear to be particularly selective in egg-laying sites, as long as they are in proximity to suitable larval host plants, and will utilize a range of plant species for oviposition (Dana, 1991). Larvae feed primarily upon Little Bluestem (*A. scoparius*), Big Bluestem (*A. gerardii*), Sideoats Grama (*B. curtipendula*) and Prairie Dropseed (*S. heterolepis*), with secondary host plants being Kentucky Bluegrass (*P. pratensis*) and Wilcox Dicanthelium (*D. wilcoxianum*) (COSEWIC, 2003). It appears that in captivity, the larvae are less selective, while in nature, they may be very host specific (Dana, 1991).

There are a number of prairie skippers which are found in close association with the Dakota Skipper. These complementary species have similar food and habitat requirements, as well as comparable flight periods to the Dakota skipper. The Dakota Skipper is most often associated with the Long Dash Skipper (*Polites mystic* (W.H. Edwards, 1863)), the Garita Skipper (*Oarisma garita* (Reakirt, 1866)), the Poweshiek Skipperling (*Oarisma poweshiek* (Parker, 1870)) and the Ottoe Skipper (*Hesperia ottoe* (W.H. Edwards, 1866)) and less commonly with the European Skipper (*Thymelicus lineola* (Ochsenheimer, 1808)), Peck's Skipper (*Polites coras* (Cramer, 1775)), the Tawny-edge Skipper (*Polites thermistocles* (Latreille, 1824)) the Pawnee Skipper (*Hesperia leonardus pawnee* (Harris, 1862)) and the Assiniboine Skipper (*Hesperia assiniboina* (Lyman, 1892)) (Environment Canada, 2007).

The Tall-Grass Prairie Preserve

In 1987, the Manitoba Naturalists Society's Tall-Grass Prairie Conservation Project was initiated and included the first systematic inventory of Manitoba's remaining tall-grass prairie communities (Joyce and Morgan, 1989). The largest remaining tall-grass prairie sites

in Manitoba were found around Tolstoi, Gardenton and Stuartburn (peripheral sites of the original prairie biome) (Joyce and Morgan, 1989; Manitoba Conservation, 2007). These areas had been considered unsuitable for agricultural cultivation, due to the presence of large boulders and swampy areas (Joyce and Morgan, 1989; Manitoba Conservation, 2007). In 1989, the Manitoba Critical Wildlife Habitat Program, began to secure land in the Tolstoi area to form the Tall Grass Prairie Preserve (TGPP), which is over 3000 hectares in size (Manitoba Conservation, 2007). The prairie is supported by contributing partners, including the Canadian Wildlife Service, the Local Advisory Committee, Manitoba Conservation, the Manitoba Habitat Heritage Corporation, the Manitoba Naturalists Society and the Nature Conservancy of Canada (Manitoba Conservation, 2007).

The TGPP area has traditionally been used for cattle grazing, which has allowed the survival of certain plants and animals characteristic of the tall-grass prairie biome (Morden, 2006; Manitoba Conservation, 2007). The TGPP is home to over 300 plant species, including flowers, grasses, shrubs and trees and a variety of animals such as butterflies, frogs, songbirds, and larger ungulates (Manitoba Conservation, 2007). Some of the plants and animals of the tall-grass prairie biome are threatened or endangered, such as the western prairie fringed orchid (*Plantanthera praeclara* Sheviak and Bowles) and the small white lady's slipper (*Cypripedium candidum* Muhl. ex. Willd.), and rely on the protection the preserve offers (Manitoba Conservation, 2007). The TGPP was once home to the Dakota Skipper, but this insect has been extirpated from the area (Morden, 2006).

The TGPP requires management to maintain the native plant species and prevent the overgrowth of trees and shrubs and invasion of exotic weeds (Swengel, 1998; Manitoba

Conservation, 2007). While it is not possible to closely mimic the natural disturbance regimes, management techniques aim to duplicate wildfires using controlled burning every three to five years and natural grazing with native grazers, domestic grazers or with mowing and haying (Manitoba Conservation, 2007). Prescribed burns are conducted in the spring or the fall depending upon the weather (Morden, 2006). Exotic and woody species are often removed by hand or with girdling techniques (Manitoba Conservation, 2007).

Study Objective

The objective of this study was to compare the vegetative composition of previously burned sites with and without grazing to determine which sites represented the best potential Dakota Skipper habitat. In addition, the purpose of the study was to survey the butterfly species and determine if there were complementary skipper species present. I tested the null hypothesis that overall plant diversity and structure was similar between different management regimes. The principal intention of this study was to make predictions concerning the management practices most conducive to re-introduction of *Hesperia dacotae* into the TGPP.

Methods and Materials

Study Area: The Tall Grass Prairie Preserve

The Tall Grass Prairie Preserve (TGPP) is located in the south-eastern portion of the province of Manitoba, near Tolstoi (49° 5'9.06"N, 96°48'30.46"W) (Figure 2, 3). Only the southern portion of the preserve was used in this study (Figure 2, 3). A boreal continental climate persists in the TGPP area, with a mean January temperature of -17.4°C, a mean July temperature of +18.7°C and an annual mean temperature of +2.4°C (Environment Canada, 2002; Westwood and Borkowsky, 2004). Temperature normals are based on data collected between 1971 and 1998, at the Sprague weather station (Environment Canada, 2002), which is approximately 85.3 kilometres east of the study area. The yearly precipitation is 610.1 mm, with 487.1 mm in the form of rain and 123 mm as snowfall (Environment Canada, 2002). The majority of precipitation (54%) falls during the period of May to August (Environment Canada, 2002).

The parent surface material is lacustrine with a thin layer of black to dark gray chernozemic soils on sandy and clay loam upper horizons (Canada Soil Inventory, 1989). The terrain has poor drainage and large stones, rocks and boulders present (Canada Soil Inventory, 1989; Westwood and Borkowsky, 2004). The vegetation is dominated by grasses, including Big Bluestem (*A. gerardii*) and Little Bluestem (*S. scoparium*), as well as forbs (Westwood and Borkowsky, 2004). There are also bluffs consisting of deciduous tree species dominated by willow species (*Salix spp.*) and poplars (*Populus spp.*) (Westwood and Borkowsky, 2004).

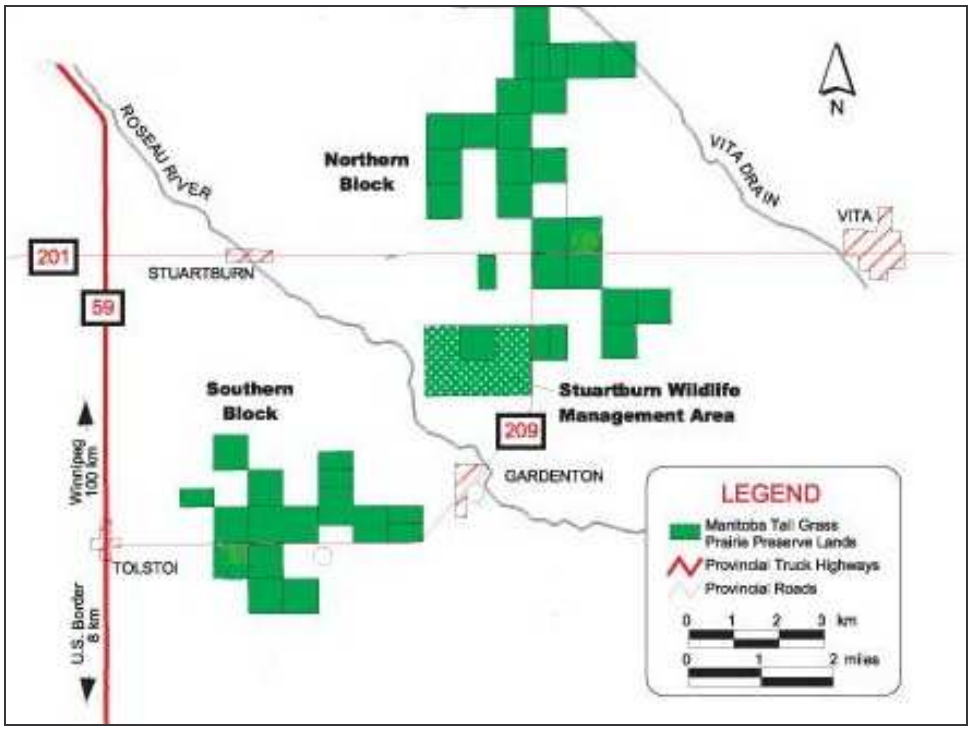

Figure 2: Map of the Tall Grass Prairie Preserve (Manitoba Conservation, 2007).

Experimental Procedures

Eight study sites chosen within the southern portion of the TGPP based upon the burn management history (Figure 3) (Morden, 2006). Morden (2006) examined several sites in the northern portion of the TGPP. The southern portion of the preserve had not been assessed for the presence of adult and larval plant requirements for the Dakota Skipper and the management regime was better documented; consequently, study sites were confined to the southern portion of the TGPP. An attempt was made to choose a range of vegetative recovery ages since the last burn, during site selection. Three treatments were chosen, based upon the burn history: last burned in 1993, 1998 and 2002. One section of land found for the 1998 burn year was enclosed by fencing and would be grazed by cattle, during the summer of 2006. Therefore the 1998 treatment was divided into two

sub-treatments: one with grazing and one without. The four treatments were as follows: 1993 burn, 1998 burn, 1998 burn with grazing and 2002 burn. Two replicates were randomly established within each treatment area.

Within each replicate, two 150 metre transects were established and marked at 25 metre intervals. The two transects were oriented in a north/south and east/west directions, with the exception of one in the 1993 burn treatment site, where the east/west transect was oriented northwest/southeast due to site size limitations. The ends of the two transects within a replicate were separated by approximately 10 metres. Within each replicate, the two transects occupied an area encompassing approximately 2.4 hectares. For each of the eight replicates, a geographical positioning system (GPS) was used to record the plot location (Figure 3, Table 1). Transects were marked with wooden stakes and flagging tape at each end and metal pins at the 25 metre intervals between.

Table 1: The land section and GPS coordinates for the replicates of the four treatment types.

Treatment Type (Section)	*Coordinates for Transects*	
1. 1993 Burn		
Replicate 1 (SW31-1-6E)	N49°04.578'	W096°47.047'
Replicate 2 (SW31-1-6E)	N49°04.806'	W096°47.024'
2. 1998 Burn		
Replicate 1 (S1/2 NW33-1-6E)	N49°05.287'	W096°43.964'
Replicate 2 (S1/2 NW33-1-6E)	N49°05.352'	W096°44.316'
3. 1998 Burn with Grazing		
Replicate 1 (S1/2 32-1-6E)	N49°04.621'	W096°45.629'
Replicate 2 (S1/2 32-1-6E)		
4. 2002 Burn		
Replicate 1 (NW32-1-6E)	N49°05.298'	W096°45.175'
Replicate 2 (NW32-1-6E)	N49°05.308'	W096°45.451'

Figure 3: Enlarged aerial photograph of the southern portion of the Tall Grass Prairie Preserve (Figure 2) showing the two replicates within each treatment type (Google Earth, 2005).

Vegetation Surveys

Vegetation was sampled three times in each of the eight replicates; once during June, July and August of 2006. For the month of July, sampling was restricted to only plants that were in flower. Percent cover of herbaceous (herbs) plants and grasses was assessed using a 1 x ½ metre quadrat and percent cover of shrubs and trees was assessed using a 1 x 1 metre quadrat. The 1 x ½ m quadrats were nested within the 1 x 1 m quadrats. Eleven 1 x 1 m quadrats were randomly assigned along each transect using a random numbers table. Marking pins were used to permanently identify the position of the 1 x 1 m quadrat placements during the first sample period in June. The random sampling points were recorded and the quadrats were placed in the same position in relation to the marking pins for subsequent July and August sample periods. The plots were sampled for

herbs and grasses in June and August, shrubs in June and July (if flowering in July) and trees only in June. All vascular plant species were identified and percent cover was recorded for each quadrat. The identifications were based on Looman and Best (1979), Looman (1982), Johnson *et al.* (1995), Vance (1999), Kershaw (2003), Moore (2003) and Staniforth (2006).

Biomass Surveys

To assess the biomass present in each of the treatments, the above ground plant material was removed from a ½ x ½ metre area. All vegetation within the ½ x ½ m area was clipped to the ground level, removed and placed in a plastic bag for transport to the laboratory, where it was dried and weighed. In the spring of 2006, grass samples were collected in the 1993 burn, the 1998 burn and the 2002 burn to conduct a preliminary biomass assessment. Six samples (½ x ½ m) were collected from each of the treatment burn years by choosing quadrats randomly in the treatment area, as permanent transects had not yet been established. In the fall of 2006, biomass sampling included the 1993, 1998, and 2002 burn treatments, as well as the 1998 burn with grazing. Ten samples (½ x ½ m) were collected per transect by placing two quadrats randomly near the 25 m metal marking pins.

Butterfly Surveys

In each replicate, butterflies surveys were performed in the area surrounding the transects. The surveys were performed in the last week of June and the first two weeks of July, which coincides with the flight period of the Dakota Skipper populations in the inter-lake region of Manitoba (Morden, 2006). Areas surrounding each transect were surveyed by sweep-netting technique for 20 to 40 minutes once a week for three consecutive weeks.

Butterflies were identified on wing or with the capture/release technique whenever possible or with captured specimens. The captured specimens were later pinned and spread for laboratory identification, which was accomplished with butterfly field guides (Klassen *et al.*, 1989; Layberry *et al.*, 1998).

Statistical Analysis

The mean percent cover of each vascular plant species was determined for each replicate with the observations from the months of June and August pooled. A master list of all species identified during the sampling periods in June and August was kept to compare the presence of species in each replicate in the four treatments. The mean percent cover of July vegetation in flower was calculated for each replicate. The mean biomass weight was calculated for each replicate in the fall and in the spring for each treatment. The mean percent cover of larval host plants and adult nectar plants were also analyzed individually.

Diversity Indices

Diversity measures are popular in ecological studies as indicators of habitat health (Magurran, 1988, 2004). Diversity has two components, which are species richness and species evenness (Magurran, 1988, 2004). Species richness is a simple count of the number of species present or a measure of the species density, while species evenness is a measure of the relative abundances of species (Magurran, 1988, 2004). Diversity indices combine the two components of species richness and evenness and differ in the relative weighting that they contribute to each (Magurran, 1988, 2004). This allows the quantification of diversity and the comparison between treatments and provides information about

commonness or rarity of species (Magurran, 1988, 2004). These measures of the diversity include alpha (α) diversity, which is a measure of diversity at the individual site level, and beta (β) diversity, which is a measure of how different or similar a range of habitats are in terms of species variety and abundance (Magurran, 1988).

Shannon's Diversity Index

The Shannon's Diversity Index (*H'*) is an α index based upon the proportional abundances of species and gives a single figure for the measurement of diversity (Magurran, 1988, 2004). The Shannon Index makes no assumptions about the underlying species abundance distribution but does assume that individuals are randomly sampled from an indefinitely large population and that all species are represented in the sample (Magurran, 1988):

$$H' = -\Sigma p_i \ln p_i$$

The proportion of the *i*th species is calculated (p_i) and multiplied by the natural logarithm of this value ($\ln p_i$) (Magurran, 1988). The products for all the species are summed and multiplied by -1 (Magurran, 1988). The value for the Shannon Index usually falls between 1.5 and 3.5, with higher values indicating higher species diversity (Magurran, 1988). The mean percent cover for each plant species was used to calculate Shannon's Diversity for each replicate in the four treatments.

Shannon's Evenness

The Shannon's Diversity Index accounts for the relative abundance of the species, but a separate measurement of evenness can be calculated, called Shannon's Evenness (*E*) (Magurran, 1988). Shannon's Evenness (E) is a measure of how similar species are in

abundances, as the ratio of observed diversity to maximum diversity (Magurran, 2004). Similarly to the Shannon Index, this measurement of evenness assumes that all the species are represented within the sample (Magurran, 1988):

$$E = H'/H_{max} = H'/\ln S$$

The value for *E* falls between zero and one, where one would represent a situation in which all species were equally abundant and zero the complete dominance of one species (Magurran, 1988, 2004). The mean percent cover for each plant species was used as in Shannon's Diversity calculations.

Rarefaction

This technique uses an algorithm to repeatedly resample individuals or samples from the total population and results in a rarefaction curve that can be used to approximate the number of species for a given sample size (Magurran, 1988; Buddle *et al.*, 2005). Rarefaction is especially useful in cases where rare species may occur in some replicates and are absent in others (Westwood, 2007). Sample-based rarefactions can account for treatment heterogeneity, when each site has been comparatively sampled (Buddle *et al.*, 2005). The advantages to this technique are it allows the statistical comparison of species richness, the estimates of species richness can be used as a diversity index and the rate of accumulation of new species can be investigated (Buddle *et al.*, 2005). There may be a problem with the loss of information when using rarefaction, because all that remains is the expected number of species per sample (Magurran, 1988). Despite this, rarefaction usually proves more accurate than other diversity indices in estimating species richness (Magurran, 2004).

$$E(S) = \Sigma\{1-[((N-N_i)/n)/(N/n)]\}$$

Here, $E(S)$ is the expected number of species, n the standardized sample size, N the total number of individuals recorded and N_i the number of individuals in the ith species (Magurran, 1988). Rarefied species richness for the number of individuals collected enables more accurate comparisons of diversity between sites and displays any insufficient sampling (Buddle *et al.*, 2005). Rarefaction can also be used for plants with multiple individual estimates of percent cover per replicate (Doak and Loso, 2003). In this case, presence/absence values are substituted for percent cover measures per sample quadrat (Doak and Loso, 2003). The number of occurrences for each plant species was determined for the combined months of June and August. The EcoSim software program was used to run a simulation to give the number of species for a given sample (Gotelli and Entsminger, 2005). Rarefaction curves were then plotted using SigmaPlot (Systat, 2004a).

Rank/Abundance

Rank/abundance plots allow for the visual assessment of treatments by plotting the species in sequence from most to least abundant (Magurran, 1988, 2004). The log normal distribution can be applied to species abundance data with any of the log base values (Magurran, 1988). It is common to use $\log_{10}$ of the percentage abundances (Magurran, 2004). Rank/abundance plots are effective in displaying species richness along with the differences in evenness among the species (Magurran, 2004). The slope of the linear regression line from the rank/abundance plot can be used to compare the different treatments (Magurran, 2004). This equates the diversity of the site with the slope of the regression line and analysis of variance can be used to compare the treatment types

(Magurran, 2004). In the present study, the mean percent cover for each species within a replicate was ranked from largest to smallest, transformed with the base 10 logarithm and the slope of the regression line was determined using the SPSS statistical package (SPSS, 2001).

Cluster Analysis

Cluster analysis uses similarity coefficients to measure the β diversity of pairs of sites (Magurran, 1988). One commonly used similarity coefficient is the Jaccard Index (C_j), which is simple and easy to calculate (Magurran, 1988). It does not utilize species abundance but rather presence/absence (Magurran, 1988):

$$C_j = j/ (a+b-j)$$

Here *j* is the number of species found in both sites, *a* the number of species in site A and *b* the number of species in site B (Magurran, 1988). The index ranges from zero to one with one indicating complete similarity between sites (Magurran, 1988). Cluster analysis pairs the two most similar sites into a single cluster and then successively clusters similar sites until all are combined in a dendrogram for visual inspection (Magurran, 1988). Two common methods of joining the clusters are average clustering and centroid clustering (Magurran, 1988). For this study, average clustering was chosen. Cluster analysis can be computed using presence/absence data or with quantitative data and the former was chosen for this analysis (Magurran, 1988). The β diversity values were then calculated with Jaccard's Index using the Systat statistical program and a cluster matrix and dendrogram were produced (Systat, 2004b).

Analysis of Variance (ANOVA)

Species richness, Shannon's Diversity, Shannon's Evenness, Rarified Species Richness, slope of regression line for Rank/Abundance plots, mean spring and fall biomass and mean percent cover of larval host plants and adult nectar sources were used to compare between treatment types using a one-way ANOVA, with a significance level set at $p \leq 0.05$ (SPSS, 2001). When ANOVA was significant, post-hoc analysis was performed using Tukey's Honestly significant difference (HSD) test (SPSS, 2001).

Results

The ranked mean percent plant species cover for each replicate of the four treatments for June and August are shown in Tables 2 to 5. In all of the treatments, grass species had the highest prevalence and contributed most of the ground cover. Shrubs and sedges also had high percent cover scores and there were lesser amounts of herbaceous species. The total number of plant species found in the months of June and August was 112 (Appendix A).

Table 2: List of ranked mean percent cover of vascular plant species found in burn year 1993 (Treatment 1)[1].

Species Name	Replicate 1	Species Name	Replicate 2	Species Name	Replicate 1	Species Name	Replicate 2
Andropogon gerardii	25.95	*Andropogon gerardii*	24.14	*Krigia biflora*	0.20	*Hypoxis hirsuta*	0.20
Grass spp.	20.68	*Grass spp.*	17.05	*Lycopus americanus*	0.20	*Solidago rigida*	0.20
Sorghastrum nutans	7.91	*Sorghastrum nutans*	7.27	*Senecio pauperculus*	0.20	*Unknown 1*	0.20
Salix spp.	6.05	*Spartina gracilis*	6.41	*Aster laevis*	0.18	*Deschampsia caespitosa*	0.16
Muhlenbergia glomerata	4.73	*Galium boreale*	2.32	*Equisetum hyemale*	0.18	*Sisyrinchium montanum*	0.11
Spartina gracilis	2.73	*Koeleria gracilis*	2.32	*Solidago missouriensis*	0.18	*Solidago graminifolia*	0.11
Potentilla fruticosa	2.32	*Zizia aptera*	1.91	*Antennaria microphylla*	0.16	*Vicia americana*	0.11
Fragaria virginiana	2.16	*Potentilla fruticosa*	1.64	*Aster umbellatus*	0.16	*Erigeron spp.*	0.09
Zizia aptera	1.66	*Carex spp.*	1.41	*Petalostemon purpureum*	0.14	*Rudbeckia serotina*	0.09
Solidago rigida	1.55	*Fragaria virginiana*	1.25	*Erigeron spp.*	0.11	*Salix spp.*	0.09
Carex spp.	1.36	*Aster ericoides*	1.02	*Lobelia spicata*	0.11	*Thalictrum venulosum*	0.09
Solidago canadensis	1.36	*Juncus balticus*	1.00	*Parnassia palustris*	0.11	*Aster laevis*	0.07
Unknown 1	1.23	*Juncus spp.*	0.93	*Prunella vulgaris*	0.11	*Helianthus maximilianii*	0.07
Aster ericoides	0.93	*Parnassia palustris*	0.77	*Aster spp.*	0.09	*Petalostemon purpureum*	0.07
Juncus balticus	0.57	*Viola nephrophylla*	0.75	*Deschampsia caespitosa*	0.09	*Poa pratensis*	0.07
Juncus spp.	0.41	*Solidago canadensis*	0.70	*Rudbeckia serotina*	0.07	*Lithospermum canescens*	0.05
Galium boreale	0.39	*Thalictrum dasycarpum*	0.68	*Lobelia kalmii*	0.05	*Pedicularis canadensis*	0.05
Viola nephrophylla	0.39	*Solidago spathulata*	0.64	*Populus tremuloides*	0.05	*Senecio spp.*	0.05
Zizia aurea	0.34	*Glycyrrhiza lepidota*	0.45	*Solidago spp.*	0.05	*Stellaria longifolia*	0.05
Eleocharus spp.	0.32	*Zizia aurea*	0.45	*Trifolium spp.*	0.05	*Glaux maritima*	0.02
Hypoxis hirsuta	0.32	*Equisetum arvense*	0.43	*Castilleja coccinea*	0.02	*Helianthus spp.*	0.02
Helianthus spp.	0.25	*Muhlenbergia glomerata*	0.32	*Lithospermum canescens*	0.02	*Lithospermum angustifolium*	0.02
Sisyrinchium montanum	0.25	*Eleocharus spp.*	0.27	*Poa pratensis*	0.02	*Polygala senega*	0.02
Rosa arkansonia	0.23	*Lysimachia quadrifolia*	0.27	*Tofieldia glutinosa*	0.02	*Solidago missouriensis*	0.02
Solidago decumbens	0.23	*Equisetum hyemale*	0.25	*Vicia americana*	0.02	*Zygadenus elegans*	0.02
Agrostis spp.	0.20	*Krigia biflora*	0.23				

[1]See Appendix A for all species identified in June and August.

Table 3: List of ranked mean percent cover of vascular plant species found in burn year 1998 (Treatment 2)[1].

Species Name	Replicate 1	Species Name	Replicate 2	Species Name	Replicate 1	Species Name	Replicate 2
Andropogon gerardii	25.95	*Andropogon gerardii*	24.14	*Krigia biflora*	0.20	*Hypoxis hirsuta*	0.20
Grass spp.	20.68	*Grass spp.*	17.05	*Lycopus americanus*	0.20	*Solidago rigida*	0.20
Sorghastrum nutans	7.91	*Sorghastrum nutans*	7.27	*Senecio pauperculus*	0.20	*Unknown 1*	0.20
Salix spp.	6.05	*Spartina gracilis*	6.41	*Aster laevis*	0.18	*Deschampsia caespitosa*	0.16
Muhlenbergia glomerata	4.73	*Galium boreale*	2.32	*Equisetum hyemale*	0.18	*Sisyrinchium montanum*	0.11
Spartina gracilis	2.73	*Koeleria gracilis*	2.32	*Solidago missouriensis*	0.18	*Solidago graminifolia*	0.11
Potentilla fruticosa	2.32	*Zizia aptera*	1.91	*Antennaria microphylla*	0.16	*Vicia americana*	0.11
Fragaria virginiana	2.16	*Potentilla fruticosa*	1.64	*Aster umbellatus*	0.16	*Erigeron spp.*	0.09
Zizia aptera	1.66	*Carex spp.*	1.41	*Petalostemon purpureum*	0.14	*Rudbeckia serotina*	0.09
Solidago rigida	1.55	*Fragaria virginiana*	1.25	*Erigeron spp.*	0.11	*Salix spp.*	0.09
Carex spp.	1.36	*Aster ericoides*	1.02	*Lobelia spicata*	0.11	*Thalictrum venulosum*	0.09
Solidago canadensis	1.36	*Juncus balticus*	1.00	*Parnassia palustris*	0.11	*Aster laevis*	0.07
Unknown 1	1.23	*Juncus spp.*	0.93	*Prunella vulgaris*	0.11	*Helianthus maximilianii*	0.07
Aster ericoides	0.93	*Parnassia palustris*	0.77	*Aster spp.*	0.09	*Petalostemon purpureum*	0.07
Juncus balticus	0.57	*Viola nephrophylla*	0.75	*Deschampsia caespitosa*	0.09	*Poa pratensis*	0.07
Juncus spp.	0.41	*Solidago canadensis*	0.70	*Rudbeckia serotina*	0.07	*Lithospermum canescens*	0.05
Galium boreale	0.39	*Thalictrum dasycarpum*	0.68	*Lobelia kalmii*	0.05	*Pedicularis canadensis*	0.05
Viola nephrophylla	0.39	*Solidago spathulata*	0.64	*Populus tremuloides*	0.05	*Senecio spp.*	0.05
Zizia aurea	0.34	*Glycyrrhiza lepidota*	0.45	*Solidago spp.*	0.05	*Stellaria longifolia*	0.05
Eleocharus spp.	0.32	*Zizia aurea*	0.45	*Trifolium spp.*	0.05	*Glaux maritima*	0.02
Hypoxis hirsuta	0.32	*Equisetum arvense*	0.43	*Castilleja coccinea*	0.02	*Helianthus spp.*	0.02
Helianthus spp.	0.25	*Muhlenbergia glomerata*	0.32	*Lithospermum canescens*	0.02	*Lithospermum angustifolium*	0.02
Sisyrinchium montanum	0.25	*Eleocharus spp.*	0.27	*Poa pratensis*	0.02	*Polygala senega*	0.02
Rosa arkansonia	0.23	*Lysimachia quadrifolia*	0.27	*Tofieldia glutinosa*	0.02	*Solidago missouriensis*	0.02
Solidago decumbens	0.23	*Equisetum hyemale*	0.25	*Vicia americana*	0.02	*Zygadenus elegans*	0.02
Agrostis spp.	0.20	*Krigia biflora*	0.23				

[1]See Appendix A for all species identified in June and August.

Table 4: List of ranked mean percent cover of vascular plant species found in burn year 1998 that included grazing (Treatment 3)[1].

Species Name	Replicate 1	Species Name	Replicate 2	Species Name	Replicate 1	Species Name	Replicate 2
Grass spp.	25.32	*Grass spp.*	39.32	*Helianthus laetiflorus*	0.41	*Sisyrinchium montanum*	0.18
Andropogon gerardii	13.55	*Andropogon gerardii*	33.36	*Juncus balticus*	0.39	*Solidago graminifolia*	0.18
Spartina gracilis	12.32	*Sorghastrum nutans*	4.18	*Petalostemon purpureum*	0.34	*Viola nephrophylla*	0.18
Salix spp.	5.95	*Bromus spp.*	3.05	*Aster laevis*	0.32	*Parnassia palustris*	0.16
Sorghastrum nutans	4.36	*Potentilla fruticosa*	2.64	*Anemone canadensis*	0.30	*Prunella vulgaris*	0.16
Bromus spp.	3.23	*Solidago rigida*	2.23	*Achillea millefolium*	0.23	*Solidago ptarmicoides*	0.16
Potentilla fruticosa	3.09	*Muhlenbergia glomerata*	1.95	*Eleocharus spp.*	0.20	*Agrostis spp.*	0.14
Solidago canadensis	2.23	*Glycyrrhiza lepidota*	1.84	*Thalictrum venulosum*	0.20	*Artemisia ludoviciana*	0.14
Fragaria virginiana	2.02	*Solidago canadensis*	1.73	*Vicia americana*	0.20	*Aster simplex*	0.09
Zizia aurea	1.82	*Equisetum hyemale*	1.66	*Equisetum hyemale*	0.18	*Liatrus ligulistylis*	0.09
Galium boreale	1.77	*Zizia aptera*	1.59	*Potentilla anserina*	0.18	*Solidago spp.*	0.09
Helianthus spp.	1.41	*Fragaria virginiana*	1.05	*Lysimachia ciliata*	0.16	*Antennaria microphylla*	0.07
Juncus spp.	1.32	*Salix spp.*	1.00	*Deschampsia caespitosa*	0.14	*Melilotus alba*	0.07
Zizia aptera	1.32	*Aster ericoides*	0.86	*Rosa spp.*	0.14	*Pedicularis spp.*	0.07
Elaeagnus commutata	1.14	*Aster laevis*	0.82	*Solidago decumbens*	0.14	*Trifolium hybridium*	0.07
Koeleria gracilis	1.14	*Carex spp.*	0.59	*Apocynum cannabinum*	0.11	*Anemone canadensis*	0.05
Betula pumila	1.09	*Juncus spp.*	0.48	*Glaux maritima*	0.11	*Aster umbellatus*	0.05
Muhlenbergia glomerata	1.09	*Achillea millefolium*	0.43	*Agrostis spp.*	0.07	*Juncus balticus*	0.05
Solidago rigida	1.07	*Galium boreale*	0.36	*Liatrus ligulistylis*	0.07	*Phleum pratense*	0.05
Carex spp.	1.05	*Rudbeckia serotina*	0.34	*Comandra umbellata*	0.05	*Campanula rotundifolia*	0.02
Parnassia palustris	0.93	*Solidago decumbens*	0.32	*Lithospermum angustifolium*	0.05	*Deschampsia caespitosa*	0.02
Unknown 1	0.89	*Pedicularis canadensis*	0.27	*Lysimachia quadrifolia*	0.05	*Equisetum arvense*	0.02
Viola nephrophylla	0.75	*Zizia aurea*	0.25	*Populus tremuloides*	0.05	*Erigeron spp.*	0.02
Glycyrrhiza lepidota	0.55	*Rosa spp.*	0.23	*Aster umbellatus*	0.02	*Helianthus spp.*	0.02
Aster simplex	0.52	*Eleocharus spp.*	0.20	*Pedicularis canadensis*	0.02	*Stellaria longifolia*	0.02
Aster ericoides	0.50	*Vicia americana*	0.20	*Pedicularis spp.*	0.02	*Taraxacum officinale*	0.02
Rudbeckia serotina	0.45	*Listera borealis*	0.18	*Prunella vulgaris*	0.02	*Thalictrum dasycarpum*	0.02
Thalictrum dasycarpum	0.43	*Lithospermum canescens*	0.18	*Zygadenus elegans*	0.02	*Trifolium spp.*	0.02

[1]See Appendix A for all species identified in June and August.

Table 5: List of ranked mean percent cover of vascular plant species found in burn year 2002 (Treatment 4)[1].

Species Name	Replicate 1	Species Name	Replicate 2	Species Name	Replicate 1	Species Name	Replicate 2
Grass spp.	13.32	*Andropogon gerardii*	28.55	*Equisetum hyemale*	0.16	*Lithospermum canescens*	0.34
Spartina gracilis	7.27	*Grass spp.*	20.09	*Helianthus laetiflorus*	0.16	*Zizia aurea*	0.32
Sorghastrum nutans	6.59	*Spartina gracilis*	4.64	*Helianthus maximilianii*	0.16	*Eleocharus spp.*	0.30
Andropogon gerardii	6.36	*Salix spp.*	4.55	*Hypoxis hirsuta*	0.16	*Rudbeckia serotina*	0.30
Potentilla fruticosa	5.27	*Galium boreale*	4.20	*Pedicularis canadensis*	0.16	*Astragalus spp.*	0.27
Galium boreale	4.02	*Sorghastrum nutans*	3.77	*Sisyrinchium montanum*	0.16	*Helianthus spp.*	0.25
Salix spp.	3.64	*Potentilla fruticosa*	3.59	*Pedicularis spp.*	0.14	*Tofieldia glutinosa*	0.23
Zizia aptera	1.64	*Koeleria gracilis*	2.45	*Helianthus spp.*	0.11	*Hypoxis hirsuta*	0.18
Koeleria gracilis	1.59	*Zizia aptera*	1.93	*Solidago ptarmicoides*	0.11	*Vicia americana*	0.18
Parnassia palustris	1.34	*Muhlenbergia glomerata*	1.91	*Thalictrum dasycarpum*	0.11	*Populus tremuloides*	0.14
Carex spp.	1.25	*Corylus americana*	1.59	*Lithospermum canescens*	0.09	*Liatrus ligulistylis*	0.11
Fragaria virginiana	1.00	*Fragaria virginiana*	1.36	*Lysimachia quadrifolia*	0.09	*Poa pratensis*	0.11
Juncus spp.	0.80	*Betula pumila*	1.18	*Muhlenbergia glomerata*	0.09	*Rhubus pubescens*	0.11
Aster laevis	0.77	*Petalostemon purpureum*	1.14	*Senecio pauperculus*	0.09	*Scutellaria epilobiifolia*	0.11
Solidago spathulata	0.73	*Carex spp.*	1.05	*Achillea millefolium*	0.07	*Aster falcatus*	0.09
Solidago rigida	0.66	*Solidago rigida*	1.02	*Erigeron spp.*	0.07	*Pedicularis spp.*	0.09
Glaux maritima	0.59	*Solidago canadensis*	0.98	*Lysimachia thyrisflora*	0.07	*Sisyrinchium montanum*	0.09
Petalostemon purpureum	0.59	*Thalictrum dasycarpum*	0.98	*Poa pratensis*	0.07	*Lysimachia quadrifolia*	0.07
Populus tremuloides	0.59	*Juncus spp.*	0.86	*Solidago missouriensis*	0.07	*Polygala senega*	0.07
Juncus balticus	0.57	*Solidago spathulata*	0.86	*Thalictrum venulosum*	0.07	*Prunella vulgaris*	0.07
Krigia biflora	0.45	*Glycyrrhiza lepidota*	0.84	*Prunella vulgaris*	0.05	*Solidago spp.*	0.07
Viola nephrophylla	0.41	*Aster laevis*	0.82	*Tofieldia glutinosa*	0.05	*Stellaria longifolia*	0.07
Bromus spp.	0.36	*Thalictrum venulosum*	0.82	*Aster simplex*	0.02	*Unknown 1*	0.07
Populus balsamifera	0.36	*Parnassia palustris*	0.70	*Zizia aurea*	0.02	*Achillea millefolium*	0.05
Solidago canadensis	0.32	*Krigia biflora*	0.68			*Cypripedium calceolus*	0.05
Eleocharus spp.	0.27	*Populus balsamifera*	0.64			*Deschampsia caespitosa*	0.05
Rudbeckia serotina	0.27	*Pedicularis canadensis*	0.59			*Lysimachia terrestris*	0.05
Anemone canadensis	0.23	*Aster ericoides*	0.57			*Phalaris arundinacea*	0.05
Castilleja coccinea	0.23	*Aster spp.*	0.57			*Campanula rotundifolia*	0.02
Polygonum amphibium	0.23	*Juncus balticus*	0.57			*Castilleja coccinea*	0.02
Polygala senega	0.20	*Rhus radicans*	0.45			*Equisetum arvense*	0.02
Vicia americana	0.20	*Viola nephrophylla*	0.45			*Equisetum hyemale*	0.02
Betula pumila	0.18	*Bromus spp.*	0.36			*Sanicula marilandica*	0.02
Aster ericoides	0.16	*Glaux maritima*	0.36			*Solidago ptarmicoides*	0.02

[1]See Appendix A for all species identified in June and August.

The ranked mean percent cover of plant species in flower are shown in Table 6. Fifty-six species of plant species were observed to be flowering in July (Appendix A). Generally, the density of plants in flower was low in all treatments, which is reflected in the low percent cover values within the quadrats (Table 6). Many plant species in flower were observed in the areas surrounding transects, but were not found within the quadrats while sampling along transects.

Table 6: List of ranked mean percent cover of plants in flower found during the July sampling period for all treatments[1].

Plant Species	% Cover	Plant Species	% Cover
Treatment 1 Replicate 1		**Treatment 3 Replicate 2**	
Glycyrrhiza lepidota	0.18	*Trifolium hybridium*	0.14
Treatment 1 Replicate 2		*Rudbeckia serotina*	0.09
Asclepias incarnata	0.32	**Treatment 4 Replicate 1**	
Cicuta maculata	0.23	*Potentilla fruticosa*	1.27
Mentha arvensis	0.23	*Galium boreale*	0.18
Lysimachia quadrifolia	0.05	*Solidago ptarmicoides*	0.14
Treatment 2 Replicate 1		*Rudbeckia serotina*	0.09
Tofieldia glutinosa	0.18	*Zizia aurea*	0.09
Senecio pauperculus	0.09	*Achillea millefolium*	0.05
Castilleja coccinea	0.05	*Castilleja coccinea*	0.05
Prunella vulgaris	0.05	*Polygala senega*	0.05
Solidago canadensis	0.05	**Treatment 4 Replicate 2**	
Solidago ptarmicoides	0.05	*Potentilla fruticosa*	0.5
Treatment 2 Replicate 2		*Campanula rotundifolia*	0.18
Galium boreale	0.41	*Tofieldia glutinosa*	0.14
Potentilla fruticosa	0.36	*Prunella vulgaris*	0.09
Glycyrrhiza lepidota	0.05	*Solidago ptarmicoides*	0.09
Treatment 3 Replicate 1		*Glycyrrhiza lepidota*	0.05
Rudbeckia serotina	0.23	*Rudbeckia serotina*	0.05
Treatment 3 Replicate 1		*Zygadenus elegans*	0.05
Lysimachia ciliata	0.18		

[1]See Appendix A for all species in flower found in July.

Rarefied species richness tended to level off after approximately 200 samples (Figure 4). The replicate with the minimum estimated sample representation was in

treatment type 1 (1993 burn year), replicate 1. Using this replicate, rarefied species richness was calculated for all replicates (Table 7). Based on the rarefaction curves, increasing the sampling intensity would not have found many more species and the number of quadrats per replicate were sufficient to have accurately sampled the species present.

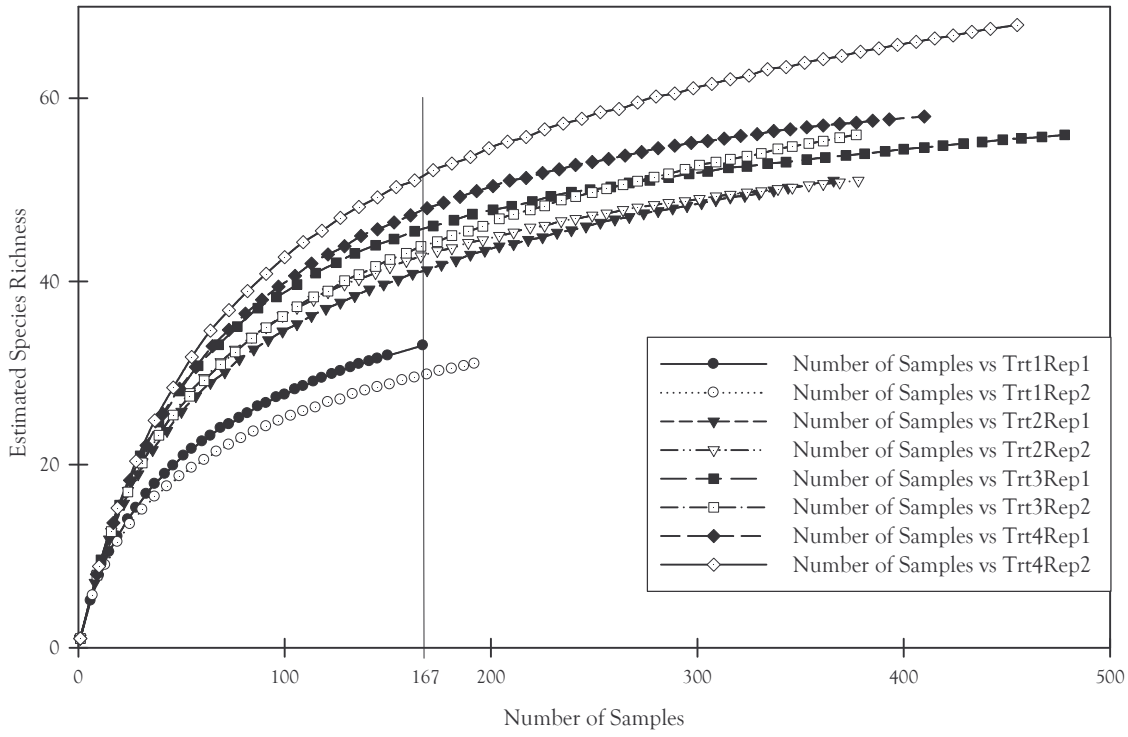

Figure 4: The rarefied species richness curves determined with EcoSim (Gotelli and Entsminger, 2005).

There were no significant differences between the treatments for Shannon's diversity or Shannon's evenness, during the June/August sampling period (Table 7). Species richness, rarefied species richness and the slope of the regression line of the rank/abundance plots differed significantly between treatments. Species richness and the

rarefied species richness were lower in the 1993 burn treatment year compared to the other three treatments (Table 7). There was also a significant difference in the slope of the rank/abundance line between treatments, with species diversity being the most even in the youngest plots (Table 7). Plant species in treatment 1 (burn year 1993) were less evenly represented than the other treatments (Table 7).

Table 7: Comparison of mean diversity values: Species Richness, Shannon's Diversity, Shannon's Evenness, Rarefied Species Richness, and Rank/Abundance.

Treatment	Species Richness	Shannon's Diversity	Shannon's Evenness	Rarefied Species Richness	Rank/Abundance
1. 1993 B	32 ± 1.00a[1]	2.02 ± 0.10	0.43 ± 0.02	31.35 ± 1.65a	-0.0801 ± 0.001d
2. 1998 B	51 ± 0.00b	2.40 ± 0.01	0.51 ± 0.00	42.05 ± 0.75b	-0.0495 ± 0.0007c
3. 1998 B & G	56 ± 0.00b	2.40 ± 0.37	0.51 ± 0.00	44.85 ± 0.85b	-0.0454 ± 0.0005b
4. 2002 B	63 ± 5.00b	2.84 ± 0.06	0.61 ± 0.02	49.65 ± 1.95b	-0.0365 ± 0.0005a
$F_{3, 7}$	27.128	3.042	2.917	30.741	766.361
p	0.004	0.155	0.164	0.003	< 0.001

[1] Means in the same column followed by different letters are significantly different (ANOVA, Tukey's HSD, $p>0.05$).

The biomass assessment showed that treatments were significantly different between the three years of burn treatment in the spring collections but not between the four treatment types in the fall collections (Table 8). The 2002 burn year had significantly less biomass than the other two burn years in the spring assessment (Table 8).

Table 8: Comparison of mean spring and fall biomass.

Treatment	Spring Biomass	Fall Biomass
1. 1993 B	107.07 ± 12.14a[1]	169.27 ± 17.75
2. 1998 B	85.11 ± 9.65a	103.12 ± 18.91
3. 1998 B&G	N/A	114.97 ± 4.47
4. 2002 B	25.00 ± 3.30b	103.32 ± 2.97
F	$F_{3, 7} = 21.539$	$F_{2, 17} = 5.679$
p	< 0.001	0.063

[1] Means in the same column followed by different letters are significantly different (ANOVA, Tukey's HSD, $p>0.05$).

There was no significant difference in the percent cover of the two main larval host plants between the treatments (Table 9). Kentucky Bluegrass (*Poa pratensis*) was almost absent in some of the treatments. Of the four plant species in flower, only the percent cover of Black-eyed Susan (*Rudbeckia serotina*) was significantly different between the treatments (Table 9). *Rudbeckia serotina* was significantly higher in the 1998 burn year with grazing and the 2002 burn year (Table 9).

Table 9: Comparison of mean percent cover of larval host plants and adult nectar sources.

Treatment	*Andropogon gerardii*[1]	*Poa pratensis*[1]	*Apocynum cannabinum*[2]	*Campanula rotundifolia*[2]	*Rudbeckia serotina*[2]	*Zygadenus elegans*[2]
1. 1993 B	3.56 ± 3.12	0.25 ± 0.25	0.17 ± 0.08	0.01 ± 0.01	0.00 ± 0.00a[3]	0.00 ± 0.00
2. 1998 B	25.04 ± 0.90	0.04 ± 0.02	0.00 ± 0.00	0.00 ± 0.00	0.08 ± 0.01a	0.01 ± 0.01
3. 1998 B & G	23.45 ± 9.91	0.00 ± 0.00	0.06 ± 0.06	0.01 ± 0.01	0.40 ± 0.06b	0.01 ± 0.01
4. 2002 B	17.45 ± 11.09	0.09 ± 0.02	0.00 ± 0.00	0.01 ± 0.01	0.28 ± 0.02b	0.00 ± 0.00
$F_{3, 7}$	1.648	0.747	2.726	0.333	39.502	0.667
p	0.313	0.578	0.179	0.803	0.002	0.615

[1]Larval Host Plants
[2]Adult Nectar Sources
[3]Means in the same column followed by different letters are significantly different (ANOVA, Tukey's HSD test, $p>0.05$).

Cluster Analysis between treatments to assess β diversity is shown in Table 10 and the resulting dendrogram in Figure 5. The results indicated that the replicates in treatment 1 (1993 burn year) were very similar and quite different from the other treatment types. Treatment 4 (2002 burn year) was more similar to treatment 2 (1998 burn year without grazing) than treatment 3 (1998 burn year with grazing).

No Dakota Skippers were caught in the TGPP during the sampling period. A list of all butterfly species caught and observed, the numbers and the date of catch are recorded in Appendix B. Complementary skippers caught and observed included Peck's Skipper (*P.*

coras), the Tawny-edged Skipper (*P. thermistocles*), the European Skipper (*T. lineola*), the Pawnee Skipper (*H. leonardus*), the Long Dash Skipper (*P. mystic*) and the Poweshiek Skipperling (*O. poweshiek*).

Table 10: Jaccard's Cluster Matrix of β diversity coefficients for comparison between treatments using Systat (Systat, 2004b).

	B[1] 1993 Rep[2] 1	B 1993 Rep 2	B 1998 Rep 1	B 1998 Rep 2	BG[3] 1998 Rep 1	BG 1998 Rep 2	B 2002 Rep 1	B 2002 Rep 2
B 1993 Rep 1	1.000							
B 1993 Rep 2	0.488	1.000						
B 1998 Rep 1	0.254	0.188	1.000					
B 1998 Rep 2	0.312	0.188	0.522	1.000				
BG 1998 Rep 1	0.309	0.192	0.446	0.529	1.000			
BG 1998 Rep 2	0.236	0.208	0.486	0.466	0.534	1.000		
B 2002 Rep 1	0.300	0.187	0.535	0.627	0.562	0.462	1.000	
B 2002 Rep 2	0.312	0.193	0.487	0.587	0.512	0.476	0.636	1.000

[1]B indicates the burn year.
[2]Rep indicates the replicate.
[3]BG indicates the treatment also included grazing.

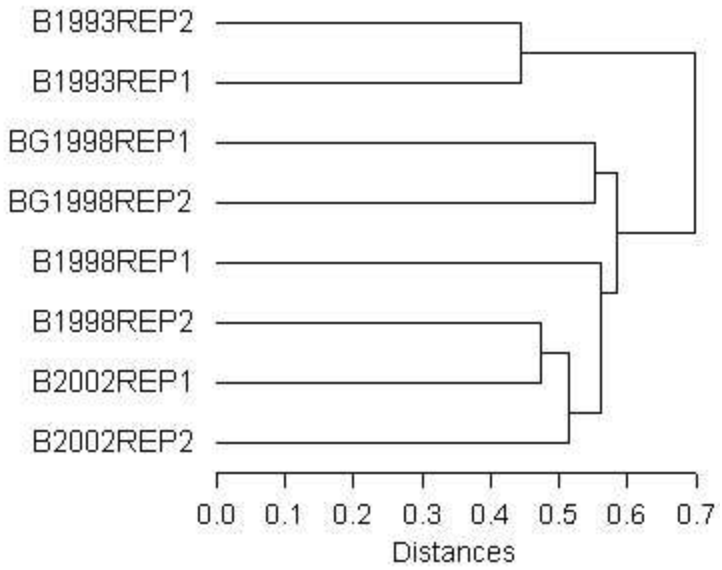

Figure 5: Jaccard's Cluster Analysis dendrogram of similarity coefficients for comparison between treatments using Systat (Systat, 2004b).

Discussion

The rankings for percent cover of the vascular plant species showed that there were some structural differences between the four treatment types. All the treatment types had high rankings for a few plant species, mostly grasses and shrubs, with most other species present in lower densities or absent. The abundance of shrubs may indicate the need for management in the TGPP, because without intervention, the shrubs may overtake the open areas and exclude the prairie grass species. In the 1993 burn, *Spartina gracilis* was the most dominant grass, whereas the other three treatments had more typical native prairie species, such as *Andropogon gerardii* and *Sorghastrum nutans*, as the dominant grasses. *Spartina gracilis* is associated with moist areas and is an erect coarse grass that is found as solitary stems or in small tufts, which would make it an unsuitable host plant for Dakota Skipper larvae (Looman and Best, 1979). The 1993 burn year also had a high percent cover of rushes (*Juncus spp.*) compared to other treatment types, which are found in wetter areas.

The rankings for percent cover of species in flower indicated a low abundance of adult nectar sources in the TGPP. None of the treatment types had high densities of plants in flower. The 1993 burn had very few plants in flower present and those that were present are not typically used by the Dakota Skipper as a nectar source. There was a slight increase in the number of species in flower found in the 1998 burn. The 1998 burn with grazing, showed a decline in the number of species found to be in flower, and this is typical of an area where cattle are present (Swengel, 2001). The 2002 burn contained the greatest number of species in flower and included *Rudbeckia serotina*, which is utilized by adult Dakota Skippers. There was no statistical difference between the treatments, when

comparing larval host plants. This was similar for the plant species in flower, except for *Rudbeckia serotina*, which was present in higher densities in the 1998 burn with grazing and the 2002 burn. The 2002 burn had both adult nectar sources and caterpillar host plants present, although it is not known if the densities are high enough to support a viable Dakota Skipper population.

Several diversity measures indicated that there was an increase in both diversity and evenness in the younger treatments. Older treatments were less diverse and were dominated by a few species. A similar trend was found for the Shannon's Diversity and Shannon's Evenness measures, but the differences were non-significant. This may be due to the fact that these are less sensitive measures of diversity and evenness than the other diversity measures. The diversity measures were in general agreement with visual inspection of the mean percent cover rankings. The slope of the rank/abundance plots indicated a statistical difference between each treatment type for evenness. The oldest treatment, the 1993 burn, was the least even, while evenness increased as the treatments became younger. The 2002 burn had the species represented most evenly. The 1993 burn may have lost some of the typical native prairie plant species (adult nectar sources and larval host plants) due to the lack of management.

The rarefied species richness curves indicated that the sampling was sufficient to account for most species and accurately represented the diversity in the treatments. The curves all leveled off at approximately the same number of samples and if the number of quadrats had been increased, there would not be many more species found. Thus increased sampling efforts would be unnecessary.

The biomass assessment in spring indicated that there were differences between the burn years in the amount of biomass present. There was a greater amount of biomass accumulated in the older 1993 and 1998 burn years, than in the 2002 burn year. This indicated that biomass accumulates as an area ages, especially in the absence of disturbance. This was not evident in the fall assessment. The spring assessment had a small sample size and may not be representative of the biomass present in the treatments. Further sampling should be performed with larger sample sizes for the spring collections.

The cluster analysis indicated that there were differences between the treatment types in the plant species that were present. Both replicates of the 1993 burn were very similar to one another and quite different from the other three treatments. This indicates less overlap of plant species between the 1993 burn and the other treatment types. The 2002 burn is more similar to the 1998 burn without grazing than the 1998 burn with grazing, and this may be due to the removal of plants by the cattle. The cluster analysis also reflects the differences between treatment types illustrated by the diversity indices.

The butterfly surveys confirmed that the Dakota Skipper has been extirpated from the area. Although there were no Dakota Skippers found, there were complementary species present; indicating that niche requirements of the Dakota Skipper may still be present in the TGPP. The Poweshiek Skipperling (*O. poweshiek*), which shares similar habitat requirements and a brief, coinciding flight period with the Dakota Skipper, was found in the TGPP (Klassen *et al.*, 1989). Like the Dakota Skipper, the Poweshiek Skipperling is dependant upon undisturbed prairie habitat and this may indicate that the Dakota Skipper could survive within this area (Layberry *et al.*, 1998).

There were some limitations in this study. The summer of 2006 was a very dry year, with almost no precipitation falling after June. This dry period may have affected the growth of plant species normally present or plant species that normally flower. For example, certain grass species may not have come to seed head during the sampling period and thus gone undetected. The dryness may have also affected the density of plant species, because in August there was very little plant cover present in some quadrats in some of the treatments. The spring was also very warm in 2006 and the butterfly species emerged earlier than normal based upon long term records (Klassen *et al.*, 1989; Layberry, 1998). This may have caused some species to be missed during sampling, as the survey started in late June.

The optimal solution for recovery and conservation of threatened and endangered prairie species would be to reverse the process of habitat loss and fragmentation (Hanski *et al.*, 1996). This may not be a reasonable goal for the TGPP, where the area for conservation is most likely near a maximum, and alternative solutions should be sought. Small reserves could be sufficient if they are connected by corridors of suitable habitat, which would allow re-colonization of burned and grazed areas (Cochrane and Delphey, 2002). While fire is utilized to maintain the TGPP, haying should also be considered. It may not be feasible to eliminate fire from the preserve by mowing trees and shrubs and haying the grasslands, as this may allow exotic species to invade, but use of fire only should not be regarded as the sole management practice to maintain prairie habitat (Swengel, 1998). At the very least, controlled burning should not be performed too frequently because certain butterfly species may benefit from an increased fire interval (Swengel and Swengel, 2001; Britten

and Glasford, 2002). Future research should focus on implementing alternative management techniques that encourage Dakota Skipper populations and studying the effects over time on the vegetative composition. Alternative management could include dividing the areas of the preserve into different treatment types, such as variable grazing intensities by different animals, burning (at different intervals and in different seasons), haying and combinations of these (Swengel, 2001). No one regime is suitable to all species of invertebrates and plants, so it is most beneficial to have a diversity of management techniques, while keeping treatments consistent within each site (Howe, 1994; Swengel, 1998). Based on the results of the current study, the 2002 burn treatment has the most potential to support the Dakota Skipper populations.

Conclusions

1. There appear to be higher levels of plant biomass in older treatments, which may influence plant evenness, making older treatments less diverse.
2. As plots age, the plant species richness and evenness decrease.
3. No Dakota Skippers were present in the Tall Grass Prairie Preserve, but many complementary skipper species were still found in the preserve.
4. Younger plots have a higher incidence of the plant species required by the larval and adult life stages of the Dakota Skipper.
5. As younger treatments have a higher density of key plants and higher diversity, they are the most suitable locations for re-introduction of the Dakota Skipper.
6. Known Dakota Skipper adult nectar sources and larval host plants occurred in low densities, even in the younger treatments and it is not known if present densities could support a re-introduction of Dakota Skippers.
7. Further research should focus on the effects of new management techniques, such as fall season haying within the Tall Grass Prairie Preserve.

References

Britten, H.B. and J.W. Glasford. 2002. Genetic population structure of the Dakota skipper (Lepidoptera: *Hesperia dacotae*): A North American native prairie obligate. *Conservation Genetics*, 3: 363-374.

Buddle, C.M., Beguin, J., Bolduc, E., Mercado, A., Sackett, T.E., Selby, R.D., Varady-Szabo, H. and R.M. Zeran. 2005. The importance and use of taxon sampling curves for comparative biodiversity research with forest arthropod assemblages. *The Canadian Entomologist*, 137: 120-127.

Canada Soil Inventory. 1989. Soil landscapes of Canada – Manitoba Land Resource Research Centre, Research Branch, Agriculture Canada, Ottawa, Canada. Agriculture Canada Publishing 5242/b. 22 pp.

Cochrane, J.F. and P. Delphey. 2002. Status assessment and conservation guidelines: Dakota Skipper, *Hesperia dacotae* (Skinner) (Lepidoptera: Hesperiidae) Iowa, Minnesota, North Dakota, South Dakota, Manitoba and Saskatchewan. U.S. Fish and Wildlife Service. Twin Cities Field Office. Minnesota, USA. 43 pp.

COSEWIC. 2003. Committee on the Status of Endangered Wildlife in Canada. COSEWIC Assessment and Status Report on the Dakota Skipper, *Hesperia dacotae*, in Canada. http://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr%5Fdakota%5Fskipper%5Fe%2Epdf. Accessed 2006, October 28.

Dana, R.P. 1991. Conservation management of the prairie skippers *Hesperia dacotae* and *Hesperia ottoe*: Basic biology and threat of mortality during prescribed burning in spring. Minnesota Agricultural Experiment Station Bulletin, 594-1991. University of Minnesota, St. Paul, USA. 63 pp.

Doak, D.F. and M.G. Loso. 2003. Effects of grizzly bear digging on alpine plant community structure. *Arctic, Antarctic and Alpine Research*, 34 (4): 421-428.

Environment Canada. 2007. Recovery strategy for the Dakota Skipper (*Hesperia dacotae*) in Canada [Draft]. *Species at Risk Act* Recovery Strategy Series. Environment Canada, Ottawa, Canada. 23 pp.

Environment Canada. 2002. Canadian Climate Normals or Averages 1971-2000. http://climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html. Accessed 2007, March 23.

Gibson, D.J. and L.C. Hulbert. 1987. Effects of fire, topography and year-to year climatic variation on species composition in tallgrass prairie. *Vegetation*, 72: 175-185.

Google. 2007. Google Earth. http://earth.google.com/ ©. Accessed 2007, February 27.

Gotelli, N.J. and G.L. Entsminger. 2005. EcoSim: Null models software for ecology. Version7.71 ©. Acquired Intelligence Inc. and Kesey-Bear. Jericho, Vermont, USA 05465. http://garyentsminger.com/ecosim.htm. Accessed 2007, March 12.

Hanski, I., Moilanen, A. and M. Gyllenberg. 1996. Minimum viable metapopulation size. *The American Naturalist*, 147(4): 527-541.

Howe, H.F. 1994. Managing species diversity in tallgrass prairie: Assumptions and implications. *Conservation Biology*, 8 (3): 691-704.

Johnson, D., Kershaw, L., MacKinnon, A. and J. Pojar. 1995. *Plants of the Western Boreal Forest & Aspen Parkland.* Lone Pine Publishing. Edmonton, Canada. pp. 1-392.

Joyce, J. and J. P. Morgan. 1989. Manitoba's tall-grass prairie conservation project. pp. 71-74. In: Bragg, T.B. and J. Stubbendieck. Editors. Prairie pioneers: ecology, history and culture: proceedings of the Eleventh North American Prairie Conference held 7-11 August 1988, Lincoln, Nebraska. http://digicoll.library.wisc.edu/cgi-bin/EcoNatRes/EcoNatRes-idx?type=header&id=EcoNatRes.NAPC11. Accessed 2007, February 27.

Kershaw, L. 2003. *Manitoba Wayside Wildflowers*. Lone Pine Publishing. Edmonton, Canada. 160 pp.

Klassen, P., Westwood, A.R., Preston, W.B. and W.B. McKillop. 1989. *The Butterflies of Manitoba*. Manitoba Museum of Man and Nature. Winnipeg, Canada. 290 pp.

Kucera, C.L. and M. Koelling. 1964. The influence of fire on composition of central Missouri prairie. *The American Midland Naturalist*, 72 (1): 142-147.

Layberry, R.A., Hall, P.W. and D.J. Lafontaine. 1998. *The Butterflies of Canada*. University of Toronto Press. Toronto, Canada. 280 pp.

Looman, J. 1982. *Prairie grasses identified and described by vegetative characters.* Agriculture Canada. Ottawa, Canada. 244 pp.

Looman, J. and K.F. Best 1979. *Budd's Flora of the Canadian Prairie Provinces*. Research Branch Agriculture Canada. Ottawa, Canada. 863 pp.

Magurran, A.E. 2004. *Measuring Biological Diversity*. Blackwell Publishing Limited. Massachusetts, USA. 260 pp.

Magurran, A.E. 1988. *Ecological Diversity and Its Measurement*. Princeton University Press. New Jersey, USA. 179 pp.

Manitoba Conservation. 2007. Manitoba's Tall Grass Prairie Preserve. Wildlife and Ecosystem Protection Branch: Critical Wildlife Habitat Program. http://www.gov.mb.ca/conservation/wildlife/managing/cwhp_tgp.html. Accessed 2007, February 27.

McCabe, T.L. 1981. The Dakota Skipper, *Hesperia dacotae* (Skinner): Range and biology, with special reference to North Dakota. *Journal of the Lepidopterists' Society*, 35 (3): 179-193.

Moore, J. 2003. *Common Native Pasture Plants of Southern Manitoba: A Landowner's Guide*. Critical Wildlife Habitat Program. Winnipeg, Canada. 77 pp.

Morden, C-J. 2006. Potential reintroduction of the Dakota skipper (*Hesperia dacotae*) into south-eastern Manitoba. Submitted in partial fulfillment of the Honours Thesis (BIOL 4111/6) course. Department of Biology, University of Winnipeg. Winnipeg, Canada. 53 pp.

Panzer, R. 2002. Compatibility of prescribed burning with the conservation of insects in small, isolated prairie reserves. *Conservation Biology*, 16 (5); 1296-1307.

Panzer, R. and M. Schwartz. 2000. Effects of management burning on prairie insect species richness within a system of small, highly fragmented reserves. *Biological Conservation*, 96: 363-369.

Samson, F. and F. Knopf. 1994. Prairie conservation in North America. *BioScience*, 44 (6): 418-421.

Schlicht, D. 1997. Population monitoring for prairie butterflies in Minnesota: Final Report. Minnesota Department of Natural Resources Natural Heritage and Non-game Research Program. Iowa Lepidoptera Project, Iowa, USA. 27 pp.

SPSS. 2001. SPSS for Windows, Release 11.0.1 ©. SPSS Inc. Chicago, Illinois, USA 60606.

Staniforth, R. 2006. University of Winnipeg. Winnipeg, Canada R3B 2E9. Personal Communication.

Swengel, A.B. 2001. A literature review of insect responses to fire, compared to other conservation managements of open habitat. *Biodiversity and Conservation*, 10: 1141-1169.

Swengel, A.B. 1998. Effects of management on butterfly abundance in tallgrass prairie and pine barrens. *Biological Conservation*, 83 (1): 77-89.

Swengel, A.B. 1996. Effects of fire and hay management on abundance of prairie butterflies. *Biological Conservation*, 76: 73-85.

Swengel, A.B. and S.R. Swengel. 2001. Effects of prairie and barrens management on butterfly faunal composition. *Biodiversity and Conservation*, 10: 1757-1785.

Swengel, A.B. and S.R. Swengel. 1999. Observations of prairie skippers (*Oarisma Poweshiek, Hesperia dacotae, H. ottoe, H. leonardus pawnee,* and *Atrytone arogos iowa*) (Lepidoptera: Hesperiidae) in Iowa, Minnesota and North Dakota during 1988-1997. *The Great Lakes Entomologist*, 32 (4): 267-292.

Systat. 2004a. SigmaPlot for Windows. Version 9.01 ©. Systat Software, Inc. San Jose, California, USA 95110.

Systat. 2004b. Systat for Windows. Version 11.0 ©. Systat Software, Inc. Point Richmond, California, USA 92804-2028.

Vance, F.R., Jowsey, J.R., McLean, J.S. and F.A. Switzer. 1999. *Wildflowers Across the Prairies.* Douglas & McIntyre Publishing Group. Toronto, Canada. 382 pp.

Webster, R.P. 2003. 2002 Survey of the Dakota Skipper, *Hesperia dacotae* (Skinner) in Canada. Prepared for the Committee on the Status of Endangered Wildlife in Canada, Charters Settlement. New Brunswick, Canada. 46 pp.

Westwood, A.R. 2007. University of Winnipeg. Winnipeg, Canada R3B 2E9. Personal Communication.

Westwood, A.R. and C.L. Borkowsky. 2004. Sphinx moth pollinators for the endangered Western Prairie Fringed Orchid, *Platanthera praeclara*, in Manitoba, Canada. *Journal of the Lepidopterists' Society*, 58 (1): 13-20.

Appendix A: The total species lists for the June/August and July sampling periods.

June and August: All Species Sampling			July: Species In Flower Sampling	
Achillea millefolium	*Lithospermum canescens*	*Spartina gracilis*	*Achillea millefolium*	*Thalictrum dasycarpum*
Agrostis spp.	*Lobelia kalmii*	*Stachys palustris*	*Agastache foeniculum*	*Thalictrum venulosum*
Andropogon gerardii	*Lobelia spicata*	*Stellaria longifolia*	*Agoseris glauca*	*Tofieldia glutinosa*
Anemone Canadensis	*Lycopus americanus*	*Taraxacum officinale*	*Anemone canadensis*	*Trifolium hybridium*
Antennaria microphylla	*Lycopus uniflorus*	*Thalictrum dasycarpum*	*Apocynum androsaemifolium*	*Vicia americana*
Apocynum cannabinum	*Lysimachia ciliata*	*Thalictrum venulosum*	*Apocynum cannabinum*	*Zizia aurea*
Artemisia ludoviciana	*Lysimachia quadrifolia*	*Tofieldia glutinosa*	*Asclepias incarnata*	*Zygadenus elegans*
Asclepias incarnate	*Lysimachia terrestris*	*Trifolium hybridium*	*Asclepias speciosa*	
Aster ericoides	*Lysimachia thyrisflora*	*Trifolium spp.*	*Astragalus frigidus*	
Aster falcatus	*Melilotus alba*	*Triglochin maritima*	*Campanula aparinoides*	
Aster laevis	*Mentha arvensis*	*Unknown 1*	*Campanula rotundifolia*	
Aster simplex	*Mint spp.*	*Vicia americana*	*Castilleja coccinea*	
Aster spp.	*Muhlenbergia glomerata*	*Viola nephrophylla*	*Cicuta maculata*	
Aster umbellatus	*Parnassia palustris*	*Zizia aptera*	*Circium arvense*	
Astragalus spp.	*Pedicularis canadensis*	*Zizia aurea*	*Crepis tectorum*	
Betula pumila	*Pedicularis spp.*	*Zygadenus elegans*	*Cypripedium calceolus*	
Bromus spp.	*Petalostemon purpureum*		*Elaeagnum commutata*	
Campanula aparinoides	*Phalaris arundinacea*		*Erigeron philadelphicus*	
Campanula rotundifolia	*Phleum pratense*		*Galium boreale*	
Carex spp.	*Poa pratensis*		*Glycyrrhiza lepidota*	
Castilleja coccinea	*Polygala senega*		*Heliopsis helianthoides*	
Cicuta maculate	*Polygonum amphibium*		*Hieracium umbellatum*	
Comandra umbellate	*Populus balsamifera*		*Hypoxis hirsuta*	
Corylus Americana	*Populus tremuloides*		*Iris versicolor*	
Cypripedium calceolus	*Potentilla anserina*		*Liatris ligulistylis*	
Deschampsia caespitose	*Potentilla fruticosa*		*Lillium philadelphicum*	
Elaeagnus commutate	*Prunella vulgaris*		*Lobelia kalmii*	
Eleocharus spp.	*Rhubus pubescens*		*Lysimachia ciliata*	
Equisetum arvense	*Rhus radicans*		*Lysimachia quadrifolia*	
Equisetum hyemale	*Rosa arkansonia*		*Medicago sativa*	
Erigeron spp.	*Rosa spp.*		*Melilotus alba*	
Fragaria virginiana	*Rudbeckia serotina*		*Mentha arvensis*	
Galeopsis tetrahit	*Salix spp.*		*Monarda fistulosa*	
Galium boreale	*Sanicula marilandica*		*Petalostemon candidum*	
Glaux maritima	*Scutellaria epilobiifolia*		*Petalostemon purpureum*	
Glycyrrhiza lepidota	*Senecio pauperculus*		*Polygala senega*	
Grass spp.	*Senecio spp.*		*Potentilla anserina*	
Helianthus laetiflorus	*Sisyrinchium montanum*		*Potentilla fruticosa*	
Helianthus maximilianii	*Smilacina stellata*		*Potentilla norvegica*	
Helianthus spp.	*Solidago canadensis*		*Prunella vulgaris*	
Hypoxis hirsuta	*Solidago decumbens*		*Rudbeckia serotina*	
Juncus balticus	*Solidago graminifolia*		*Senecio pauperculus*	
Juncus spp.	*Solidago missouriensis*		*Sisyrinchium montanum*	
Koeleria gracilis	*Solidago ptarmicoides*		*Solidago canadensis*	
Krigia biflora	*Solidago rigida*		*Solidago ptarmicoides*	
Liatrus ligulistylis	*Solidago spp.*		*Sonchus arvensis*	
Listera borealis	*Solidago spathulata*		*Spiraea alba*	
Lithospermum angustifolium	*Sorghastrum nutans*		*Stachys palustris*	

Appendix B: A catalog of the number of butterflies and date found for each survey.

Butterfly Species	Trt1Rep1[1]	Trt2Rep1	Trt2Rep2	Trt3Rep1	Trt3Rep2	Trt4
Oarisma powesheik	1 Jul 11	3 Jun 27	3, 1 Jun 27, Jul 6	3, 4 Jun 29, Jul 5		26, 6, 3 Jun 28, Jul 6, Jul 11
Thymelicus lineola		2, 1 Jun 27, Jul 6				
Hesperia leonardus		1 Jun 27				
Polites coras	1 Jul 11	1, 1 Jun 27, Jul 6			2 Jul 5	2 Jun 28
Polites themistocles		2[2] Jul 11[2]	1 Jul 6			
Polites mystic	1 Jun 29	4 Jun 27	1 Jun 27	1 Jun 29		1 Jul 6
Poanes hobomok						1 Jun 28
Euphyes ruricola						1, 2 Jul 6, Jul 11
Wallengrenia egermet						1 Jun 28
Papilio polyxenes			1 Jun 27		1 Jul 5	
Pieris rapae	1 Jun 29		2 Jun 27		1 Jul 5	
Colias philodice				3 Jul 5		
Lycaena dorcas	1 Jul 7	2 Jul 6	2[2] Jul 11[2]	2 Jul 5		
Satyrium acadica						1 Jul 6
Everes comyntas		1 Jun 27				1 Jul 11
Speyeria cybele		2 Jun 27	1 Jun 27		1 Jul 5	1 Jun 28
Boloria selene		1 Jun 27	5 Jun 27		1 Jul 5	
Boloria bellona				1 Jul 5		
Phyciodes morpheus			5, 2 Jun 27, Jul 6	1 Jun 29	2 Jul 5	8, 1 Jun 28, Jul 6
Limenitis arthemis		1 Jun 27	3 Jun 27			
Limenitis archippus		1 Jun 27	1 Jun 27			
Satyrodes eurydice		1 Jun 27	3 Jun 27		1 Jul 5	
Cercyonis pegala	1 Jun 29				2 Jul 5	1, 1 Jun 28, Jul 6

[1]Trt indicates treatment and Rep indicates replicate.

[2]Butterflies were collected for both replicate 1 and replicate 2 of burn year 1998.