Microhabitat preferences of the prairie skink (*Plestiodon septentrionalis)*
in southwestern Manitoba

by

Jill Larkin

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ABSTRACT

In Canada, the prairie skink (*Plestiodon septentrionalis,* formerly *Eumeces septentrionalis*) exists only in southwestern Manitoba and is listed as Endangered under the Canadian Species at Risk Act. Habitat loss is the most significant threat faced by the prairie skink in Canada. Factors contributing to habitat loss include: native prairie cultivation, aspen (*Populus tremuloides*) encroachment, leafy spurge (*Euphorbia esula*) invasion, urbanization and road construction. The objectives of this study were to determine microhabitat preferences of prairie skinks, and determine the effect of leafy spurge invasion on prairie skink microhabitat and populations in southwestern Manitoba. To determine microhabitat preferences, sites used by skinks were compared to randomly located sites within the individual's home range. Artificial cover was the most important microhabitat element for prairie skinks in southwestern Manitoba during the active season. Prairie skinks did not select microhabitat based on other variables, including thermal characteristics, number of leafy spurge stems or percent cover of vegetation, exposed soil, gravel, juniper or leaf litter. The thermal characteristics of the microhabitat were further examined by comparing the temperature under cover to the surface temperature adjacent to the location where each skink was observed. When individuals were caught under cover, the temperature under the cover was significantly lower than the surface temperature. The average surface temperature was closer to the preferred body temperature of this species, suggesting that prairie skinks may use cover for reasons other than thermoregulation, such as predator avoidance and foraging. To determine the impacts of leafy spurge on the thermal characteristics of the microhabitat, iButton ® data loggers were used to compare differences in daily standard deviation, maximum and mean ground temperatures between leafy-spurge invaded and un-invaded plots at four study sites. No significant differences in temperature were observed between leafy-spurge-invaded and un-invaded plots. Using coverboard sampling, no detectable differences in prairie skink densities between leafy-spurge-invaded and un-invaded plots were observed. However, prairie skinks were significantly more likely to be found in leafy spurge patches when cover was present, than when no cover was present. Artificial cover may improve prairie skink microhabitat by altering the thermal characteristics, providing refuge from predators, and providing microhabitat for prey. Land managers should consider providing artificial cover in suboptimal habitats for prairie skink conservation in southwestern Manitoba.

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CHAPTER 1: INTRODUCTION

The prairie skink *(Plestiodon septentrionalis,* formerly *Eumeces septentrionalis)* is a small semi-fossorial lizard with snout to vent lengths ranging from 25mm in hatchlings to a maximum of 82mm in adults (Figure 1, Breckenridge 1943). Juveniles have a distinct bright blue tail, which fades after it reaches a SVL of 50mm (Breckenridge 1943). During breeding season adult males can be distinguished from females by the bright orange colouration on the male's chin (Breckenridge 1943). The prairie skink is insectivorous, feeding mainly on crickets, grasshoppers, and spiders, but cannibalism has also been observed (Breckenridge 1943; Nelson 1963). Predators include snakes, birds, house cats and other mammals. To avoid predation, prairie skinks are capable of dropping and regrowing their tails (Breckenridge 1943).

Prairie skinks hibernate underground from mid-September until mid to late April (Bredin 1988). Breeding occurs in the spring after the skinks emerge from hibernation (Breckenridge 1943). Females lay between 4 and 18 eggs in late June to early July in a cavity in the ground, under a piece of natural or artificial cover (Somma 1987b). Females exhibit brooding behaviour to regulate the water exchange across the egg shells (Somma and Fawcett 1988). Eggs hatch approximately 30 days after being laid (Somma 1987a). Maternal care of neonates for up to two days has also been observed (Somma 1987a).

Prairie skinks generally prefer areas dominated by native mixed-grass prairie vegetation on south- and west-facing slopes with high leaf litter cover and high heat absorbance (Bredin 1989; Scott 2005). To a lesser degree, prairie skinks are also found in areas with prostrate shrubs, such as creeping juniper (*Juniperus horizontalis*), which prairie skinks use for cover (Scott 2005). Ground cover is likely an important microhabitat variable, since prairie skinks, as well as other species of the *Plestiodon* genus, use cover for nesting (Fitch 1955; Breckenridge 1943; Bredin 1989; Hecnar 1994), feeding (Fitch 1955; Scott 2005), predator avoidance (Fitch 1955; Seburn 1993), and thermoregulation (Huey 1991). Prairie skinks are most frequently observed under natural or artificial cover and are rarely observed in the open (Breckenridge 1943). In the southern part of their range, they are typically found under natural cover objects, such as flat stones (Clark 1955).

In Canada, the prairie skink exists only in two small isolated populations in southwestern Manitoba. The overall range of the prairie skink in Manitoba is 1880 km^2, with only 670 km^2 of potential habitat within this area (COSEWIC 2004). The Manitoba prairie skink population is at the northern limit of this species' range and is disjunct from the rest of the North American population, which occurs over 150 km to the south, with no possibility of rescue effect (COSEWIC 2004). Prairie skinks occur here in mixed-grass prairie habitat with loose, sandy soils, which enable them to burrow below the frostline to survive the winter by hibernating for up to 7 months (Nelson 1963).

The prairie skink is significant because it is one of six native lizard species in Canada. *Plestiodon septentrionalis* is one of three species of this genus in Canada, which includes *P. fasciatus* in southwestern Ontario and *P. skiltonianus* in British Columbia. Of the three species, *P. septentrionalis* is the most geographically restricted within its Canadian range.

In Canada the prairie skink occurs only in southwestern Manitoba and it is the only lizard found in this province (COSEWIC 2004).

Habitat loss and fragmentation of the mixed-grass prairie in southwestern Manitoba is threatening the prairie skink population. Aspen (*Populus tremuloides*) encroachment as a result of fire suppression is resulting in the fragmentation and loss of the mixed-grass prairie (Samson and Knopf 1994). Fire suppression may also degrade prairie skink habitat by allowing thatch to build up. This has not been tested, but in Minnesota, prairie skink density was higher in fields that were regularly burned. Tree planting programs have also resulted in the loss of mixed-grass prairies in southwestern Manitoba (COSEWIC 2004). The mixed-grass prairie is also being lost to cultivation. For example, the area of potato fields increased from 121.41 ha in 1960, to 1335.46 ha in 1961, and 7284.34 ha in 2000 in the North Cypress area (Town of Carberry 2003). The invasion of the exotic leafy spurge (*Euphoriba esula*) is also causing a decline in native prairie vegetation (Belcher and Wilson 1989) and has been identified as one of the suspected causes of prairie skink decline in southwestern Manitoba (COSEWIC 2004). However, the impact of leafy spurge on prairie skinks has not been formally studied.

In Canada, the prairie skink was listed as Special Concern under the Species at Risk Act in 1989 and was upgraded to Endangered when it was re-assessed in 2004. A draft National Recovery Strategy for the Prairie Skink (*Eumeces septentrionalis*) was written in 2006 to set goals and objectives for prairie skink conservation efforts in Canada (Prairie Skink Recovery Team 2006). Objective # 3 of the Recovery Strategy is to "halt or reduce any further loss of mixed-grass prairie habitat quantity and quality in all known current locations, and maintain or restore where possible large contiguous blocks of mixed-grass prairie habitat and dispersal corridors through protection and management." However, since critical habitat for this species has not been defined, determining which land management activities cause habitat loss is difficult. My thesis will provide information on prairie skink microhabitat use and the impacts of leafy spurge, which can be used by the National Prairie Skink Recovery Team to help define critical habitat and reduce habitat loss in southwestern Manitoba.

Objectives

1. Determine microhabitat preferences of the prairie skink in southwestern Manitoba (Chapter 2).

2. Determine the influence of leafy spurge on the thermal characteristics of the microhabitat and prairie skink density (Chapter 3).

3. Make management recommendations for prairie skink conservation in Manitoba (Chapter 4).

Organization of Thesis

This thesis is comprised of two manuscripts, which will be submitted to peer-reviewed journals for publication. The fourth chapter is a summary of the findings and management recommendations.

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Figure 1. Adult prairie skink.

CHAPTER 2: MICROHABITAT PREFERENCS AND THE IMPORTANCE OF ARTIFICIAL COVER FOR THE PRAIRIE SKINK (*PLESTIODON SEPTENTRIONALIS*) IN SOUTHWESTERN MANITOBA

Abstract

In Canada, the prairie skink (*Plestiodon septentrionalis,* formerly *Eumeces septentrionalis*) exists only in southwestern Manitoba and is listed as Endangered under the Species at Risk Act. One of the main goals of the proposed recovery strategy for this species is to protect and restore prairie skink habitat in order to maintain self-sufficient populations. Habitat loss is the most significant threat faced by the prairie skink in Canada. Factors contributing to habitat loss include, native prairie cultivation, aspen (*Populus tremuloides*) encroachment, leafy spurge (*Euphorbia esula*) invasion, urbanization and road construction. The objective of this study was to determine microhabitat preferences of prairie skinks in southwestern Manitoba. Classification and regression tree analysis was used to compare microhabitats used by prairie skinks to randomly located sites within the individual's estimated home range. Artificial cover was the most important microhabitat element for prairie skinks in southwestern Manitoba during the active season. Prairie skinks did not select microhabitat based on thermal characteristics, number of leafy spurge stems or percent cover of vegetation, exposed soil, gravel, juniper or leaf litter. The presence of artificial cover plays an important role in prairie skink conservation in Manitoba. Land owners and managers should use artificial cover as an interim solution in areas that are under pressure from habitat loss until landscape management goals can be achieved. This would create suitable microhabitat, provide refuge from predators, increase prey abundance, provide suitable nesting sites, and provide a substrate for thermoregulation.

Introduction

The prairie skink *(Plestiodon septentrionalis,* formerly *Eumeces septentrionalis)* is a small insectivorous lizard found in the Great Plains of North America (Breckenridge 1943). In Canada, the prairie skink exists only in southwestern Manitoba, in a population that is disjunct from the main range, located approximately 150 km to the south (COSEWIC 2004). The overall extent of the prairie skink's range in Manitoba is 1880 km^2, with only 670 km^2 of potential habitat within this area (COSEWIC 2004). In Canada, the prairie skink is listed as Endangered under the Species at Risk Act, with habitat loss identified as the primary threat (COSEWIC 2004). Factors contributing to habitat loss include, native prairie cultivation for agriculture, aspen (*Populus tremuloides*) encroachment due to fire suppression, invasion of the exotic plant leafy spurge (*Euphorbia esula*), urbanization, and road construction (COSEWIC 2004). Low population density, limited dispersal, and low reproductive rates also make them vulnerable to extinction (COSEWIC 2004). Since prairie skinks are poor dispersers, there is little possibility of rescue effect from the US population (COSEWIC 2004).

An understanding of prairie skink habitat requirements is critical to addressing the issue of habitat loss. At the northern part of their range, prairie skinks require loose sandy soils, which allow them to survive the winter by burrowing below the frostline to hibernate (Breckenridge 1943). Therefore, loose soils of the Stockton Loamy Sand and Miniota Sand associations are a limiting factor in the distribution of the prairie skink in Manitoba (Bredin 1981). Prairie skinks generally prefer areas dominated by native mixed-grass prairie vegetation on south- and west-facing slopes with high leaf litter cover and high heat absorbance (Bredin 1989; Scott 2005). To a lesser degree, prairie skinks are also found in areas with prostrate shrubs, such as creeping juniper (*Juniperus horizontalis*) (Scott 2005). Juniper forms mats that are used by the skink as natural cover for feeding, avoiding predators, and thermoregulation.

Microhabitat requirements of the prairie skink in Manitoba are not well understood and have not been quantified. Ground cover is likely an important microhabitat variable, since prairie skinks, as well as other species of the *Plestiodon* genus, use cover for nesting (Fitch 1955; Breckenridge 1943; Bredin 1989; Hecnar 1994), feeding (Fitch 1955; Scott 2005), predator avoidance (Fitch 1955; Seburn 1993), and thermoregulation (Huey 1991). Prairie skinks are most frequently observed under natural or artificial cover and are rarely observed in the open (Breckenridge 1943). In the southern part of their range, they are typically found under natural cover objects, such as flat stones (Clark 1955). At the northern part of their range in southwestern Manitoba, flat rocks do not occur. Natural cover in the area is limited to small amounts of woody debris and mats of creeping juniper; however, some areas have an abundance of artificial cover objects (e.g. old fence posts, pieces of metal, railway ties, carpet, linoleum, and lumber of various sizes). In Manitoba, this species seems to prefer artificial over natural cover objects, even when natural cover, such as woody debris from fallen white spruce and aspen, is abundant (Bredin 1989). Artificial cover also appears to be important for nesting in southwestern Manitoba. Bredin (1989) found five nests in the wild, all of which were under artificial cover. Due to the pressures associated with habitat loss in southwestern Manitoba, artificial cover may be increasingly important for the conservation of the prairie skink.

Although researchers have long used artificial cover as a low-impact method of studying and monitoring reptile species (Cooper and Garska 1987; Engelstoft and Ovaska 2000; Hoare *et al*. 2009), the importance of artificial refugia in reptile microhabitat restoration is also being recognized (Hecnar and M'Closky 1998; Webb and Shine 2000; Diaz *et al*. 2006; Ross *et al*. 2008; Theiry *et al*. 2009). Like natural cover, artificial cover is used for nesting, feeding, predator avoidance and thermoregulation. Artificial cover can also be used as stepping stones for dispersal in areas of suboptimal habitat.

The objective of this study was to quantify microhabitat variables (surface temperature, cover temperature, number of leafy spurge stems, and percent cover of artificial cover, soil, gravel, juniper, leaf litter, woody debris and vegetation) for the prairie skink at the northern limit of its range during the active season (May to September). Classification and regression tree analysis was used to compare microhabitats used by skinks to randomly located sites within the individual's estimated home range. The thermal characteristics of the microhabitat were further examined by comparing the temperature under cover to the surface temperature adjacent to the location where the skink was observed. This study will provide valuable information on the prairie skink's microhabitat requirements, which can be used by land managers to prevent the degradation of prairie skink microhabitat and restore degraded microhabitat. These results can be incorporated into the National Prairie Skink Recovery Strategy and Action

Plan and will be useful in the conservation of this species in Canada.

Methods

Study Area

The study area is located within the Assiniboine River Delta, near Carberry (49°52'N, 99°21'W) in southwestern Manitoba (Figure 1). The Assiniboine River Delta is characterized by Stockton association soils developed on deep sandy deltaic deposits with surface textures varying between sand to very fine sandy loam (Schykulski and Moore 2000). These sands were deposited 11,000 years ago and were shaped into sandhills by eolian activity (Upham 1895). The majority of the sandhills have since been stabilized by grassland, aspen parkland, and forest communities (Bird 1927; Wolfe *et al.* 2000).

The vegetation community of the study area is unique because it is located in the transition zone between prairie and deciduous forest types, and also includes boreal forest remnants. Five distinct vegetation communities have been identified in the area, including sand plain, prairie, deciduous forest, mixed forest, and larch swamp (Bird 1927). The sand plain community consists of bare sand interspersed with isolated individuals and clumps of vegetation. The prairie community is dominated by grasses, with sedges and flowering plants. Lichens grow in sandier regions of the prairies and the knolls are covered with *Juniper horizontalis*. The deciduous forest community is dominated by trembling aspen (*Populus tremuloides*), with the exception of wetter areas where balsam poplar (*Populus balsamifera*) and bur oak forest (*Quercus macrocarpa*) dominate. The mixed forest community is composed of white spruce (*Picea glauca*), trembling aspen, bur oak, and willow. The larch swamp community is dominated by tamarack (*Larix laricina)* and dwarf birch (*Betula glandulosa).* Prairie skinks have been observed in all five vegetation communities to varying extents.

The vegetation cover in the study area has changed dramatically in the past 150 years (Schykulski and Moore 2000). Three major changes have been observed: 1) the vegetation cover has increased resulting in the stabilization of the sand dunes, 2) the amount of prairie has decreased due to the encroachment of woody vegetation, and 3) the exotic invasive plant, leafy spurge, has taken over many areas of mixed-grass prairie aggressively out-competing native species.

The study area lies within the subhumid climatic zone (Wolfe *et al*. 2000). According to long-term weather data (1971-2000) collected at the nearest Environment Canada weather station (Brandon Airport), located approximately 30 km west of the study area, the mean monthly temperatures ranged from 18.4ºC in July to -18.0ºC in January (Environment Canada). Average daily maximum from May to September ranged from 16.1ºC to 24.9ºC. Average daily minimums during this time ranged from 2.6ºC to 12.9ºC. July was the warmest month, with a mean monthly temperature of 18.9ºC. During this same time frame (1971-2000) the average total annual precipitation was 472 mm. Of this precipitation, 373 mm fell as rain, and 112 mm fell as snow. The annual peak in precipitation occurred in July, with an average precipitation of 76 mm.

My study was located within Canadian Forces Base Shilo (CFB Shilo) and Spruce Woods Provincial Park. Primary land uses in this area include agriculture, military training activity, recreation and conservation. The two largest communities in the area include Carberry (population = 1,502), and Glenboro (population = 633; Statistics Canada 2006). Over the last two decades there has been an increase in agricultural activities in the areas surrounding CFB Shilo and Spruce Woods Provincial Park. This includes an increase in the number of large livestock operations (especially large scale hog barns) and potato farming (Assiniboine Aquifer Delta Round Table 2005). The annual number of visitors to Spruce Woods Provincial Park is between 60,000 and 100,000 individuals (Madelyn Robinson, personal communication).

Field sampling

To determine microhabitat selection, various sites with known prairie skink occurrences and other potential habitat across the study area were thoroughly searched between May 5 and September 16, 2008. At each site, I searched all open areas and under all existing pieces of natural and artificial ground cover, and caught the specimens by hand. This technique has proven effective for the capture of prairie skinks (Breckenridge 1943; Bredin 1999; Mullen 2006; Cairns 2007; Dransfield 2008; Rutherford 2007), and other small lizard species (Fitch 1955; Goode *et al.* 2003; Rutherford and Gregory 2003; Howes and Loughheed 2004; Du *et al.* 2006; Tocher 2006). All individuals were marked by toe clipping and placed in one of the following sex/age classes: adult female, adult male or juvenile. Individuals with a snout-to-vent length <55mm were classified as juveniles and were not sexed. Multiple indicators were used to identify the sex of each adult. Adults were sexed by probing their vent. If there were two pockets running parallel to the length of the body, opening at the two corners of the vent running towards the posterior, the individual was identified as a male. During breeding season, the sex of a specimen was deemed male by the presence of red or orange coloration on the chin. If no pockets were evident when the probe was inserted into the vent, the individual was classed as female. An enlarged abdomen in the post breeding season also indicated female.

All prairie skinks were released at the point of capture within 30 minutes and all pieces of cover were returned to their original position. Sites were visited on a bi-weekly rotation to minimize impacts on the habitat and disturbances to prairie skinks. All techniques were approved by the Brandon University and University of Manitoba Animal Care Committees (Animal Care Permit # 2006R02).

To determine the microhabitat preferences of the prairie skink, the methods used in Howes and Lougheed (2004) were followed. Each occupied site (location where an individual was first observed) was compared with two random unoccupied sites presumed to be within the individual's home range. One unoccupied site was located 3 m (near site) from the occupied site in a random direction and the other unoccupied site was located 10 m (far site) from the occupied site in another random direction.

To indicate microhabitat preference, both near and far unoccupied sites were placed within the estimated home range of the observed individual. Nelson (1963) estimated that the diameter of the home range of *P. septentrionalis* is between 30 m and 100 m. Scott (2005) observed total movements of up to 16 m, with an average of 5.37 m per 4-hour period. A conservative home range estimate for prairie skinks (within 10 m) was used in this study.

To quantify the microhabitat in the occupied and unoccupied sites, a 1 m by 1 m quadrat was placed over the centre of each site. For occupied sites, the centre of the site was where the individual was first observed. A digital photo centered over the quadrat was taken using an Olympus FE-140 digital camera and processed in the lab (described below). The ground surface temperature and the temperature under the piece of cover were recorded in each site, using a NexxTech thermometer (model #6301035, accuracy ±1°C). Temperatures were recorded immediately after the capture. The number of leafy spurge stems in the quadrat were counted in the field.

Photo processing

For each photo, percent cover for each microhabitat element (Table 1) was estimated visually. If one or more of the three photos associated with each capture was not clear enough to accurately classify, the observation was removed from the dataset.

Statistical Analysis

I conducted Classification and Regression Tree (CART) analyses to determine the importance of the cover temperature, surface temperature, number of leafy spurge stems, and the 7 microhabitat elements on prairie skink microhabitat selection. CART analysis is a non-parametric test that is used to identify homogenous groups within the dataset defined by rules that are based on single explanatory values (De'Ath and Fabricius 2000). This test does not require normally distributed data and can deal with nonlinear relationships and high order interactions (De'Ath and Fabricius 2000). CART is a tree building method that works by recursively splitting parent nodes into two child nodes, beginning with a root node, which consists of the entire dataset. The software finds the best single variable to use to split the dataset into two nodes, by checking all possible splits to maximize the homogeneity of each child node. The splitting is continued until it is not possible to split the data anymore or a limit set by the user is reached. Once the tree building has stopped, the tree is pruned, starting with the terminal child nodes. If the split does not add additional accuracy to the model, it is removed.

The analysis was repeated four times, first on the entire dataset (n=117), then by age/sex class (adult female: n=43, adult male: n=41, juvenile: n=33) to determine if the age/sex classes preferred different microhabitats. I removed recaptures from the analysis if the individual was recaptured under the same piece of cover. Adults of unknown sex (n=1) were left in the analysis of the entire dataset, but were removed from the analyses of the female and male data subsets. The unoccupied near and far sites were pooled. In the model, I set the maximum tree depth at three levels, the minimum number of observations for the parent nodes was 20 and the minimum number of observations for the child nodes was 10.

A paired *t*-test was used to determine if there was a difference between the capture temperature and the surface temperature at the occupied sites. The capture temperature was taken under the piece of cover. A dataset collected over the 2007 and 2008 field seasons was used in this analysis (*n*=384). All statistical analyses were performed using PASW 18 Statistics software (formerly SPSS Statistics).

Results

A total of 117 individuals were captured: 42 adult females, 41 adult males, 33 juveniles, and 1 adult of unknown sex. All individuals were caught in Stockton Loamy Sand association soils across a wide variety of habitat types including sand plain, native prairie, deciduous forest (dominated by trembling aspen), mixed forest, and larch swamp. All individuals captured in deciduous and mixed forests were found on the edges of these habitats. Skinks were caught in areas with various land uses, including goat and cattle grazing, recreation, military training, farm yards and gardens. Of the 117 captures, the majority (85.5%) of the individuals were caught under various types of cover, including plywood (55.5%, *n*=65), lumber (7.7%, *n*=9), wood paneling (6.8%, *n*=8), discarded railway ties (6.0%, *n*=7), linoleum (2.6%, *n*=3), woody debris (4.3%, *n*=5), metal (0.9%, *n*=1), tar paper (0.9%, *n*=1), and brick (0.9%, *n*=1). The remainder of the individuals (14.5%, *n*=17) were caught in the open.

Occupied sites had a higher percent of artificial cover than unoccupied sites (Figure 2). There was little difference between occupied and unoccupied sites in percent cover of bare soil, gravel, juniper, leaf litter, and woody debris or in number of leafy spurge stems, surface temperatures and capture temperatures.

The overall CART analysis revealed similar results, indicating that percent of artificial cover is the most important microhabitat feature for prairie skinks of all age/sex classes (Figure 3). With the pooled dataset, the CART analysis revealed a split in the dataset between occupied and unoccupied sites based on artificial cover (above and below 12.5%), which improved the homogeneity of the dataset by 27.3%. There was a second split in the tree on the less than 12.5% artificial cover side (below 1%, and between 1% and 12.5%), which improved homogeneity by 1.9%. A third split occurred below the less than 1% artificial cover and the data were split based on the presence of woody debris (above and below 2.5%), which improved heterogeneity by 1.4%. Overall, 90.6% of all sites were correctly classified in this model. The separate CART analyses for males, females and juveniles revealed similar results (Figures 4, 5 and 6). In all models, artificial cover provided the largest improvement in the models (26-30%). Woody debris was not an important microhabitat element in the three sex/age classes models.

Paired t-tests indicated that, for individuals caught under cover, the surface temperature was significantly higher than the temperature under cover (surface temperature=28.02±0.35ºC, cover temperature=24.78±0.30ºC; t=12.69, df=382, p<0.001).

Discussion

Artificial cover is clearly the most important microhabitat element for prairie skinks in Manitoba during the active season when they are not hibernating or nesting. Prairie skinks did not select microhabitat based on vegetation, which is consistent with prairie skink microhabitat use in Minnesota (Pitt 2001). Amount of bare ground, exposed soil, juniper, and leaf litter did not play a role in microhabitat selection. Woody debris played a secondary role (only in the pooled dataset), although this term provided little improvement in the model (<2%).

The importance of cover for reptiles is well documented. Five-lined skinks (*P. fasciatus*) in the boreal shield are associated with loose rock cover (Howes and Lougheed 2004), whereas populations of this species in southwestern Ontario are associated with large wood debris (Seburn 1993; Hecnar and M'Closky 1998). This difference in microhabitat use represents a difference in the available microhabitat between the two study areas. The most important microhabitat feature associated with predicting the presence of *P inexpectatus* is coarse woody debris (Greenburg *et al*. 1994). *P.obsoletus* is also a sedentary species that is commonly found under cover and has been observed nesting under rock cover (Fitch 1955).

The use of artificial cover to create microhabitat for reptiles in sub-optimal microhabitats has been recommended by various authors. For example, for the conservation of the eyed-lizard *(Lacerta lepida*) in central Spain, Diaz *et al*. (2006) recommends the use of artificial cover sites in areas where stone and boulder refuges have been removed for agricultural purposes. Ross *et al*. (2008) suggests that artificial cover could be used to restore degraded habitats for orange-tailed skinks (*Gongylomorphus spp.*), which are endemic to Flat Island, Mauritius. Artificial cover could be used to enhance habitat by acting as stepping stones for dispersal between optimal habitats. This could promote gene flow between small isolated populations, which may help to avoid inbreeding and increase population sizes. In southern Ontario, microhabitat restoration experiments were conducted where *P. fasciatus* microhabitat has been reduced due to human disturbance and the removal of woody debris (Hecnar and M'Closky 1998). This study found that artificial cover increased skink activity, but also noted that partially decayed woody debris was required for nesting. Theirry *et al*. (2009) compared the thermal properties of three different types of artificial cover and determined the preference of the nocturnal common gecko (*Hoplodactylus maculatus*) and diurnal McCann's skink (*Oligosoma maccanni*) in New Zealand. For the conservation of endangered Iberian rock lizards (*Iberolacerta cyrenilizard*) inhabiting ski hills, Amo *et al.* (2007) recommends the use of artificial cover to create refuges that can be used as corridors between suitable patches of microhabitat. In British Columbia, where fire suppression is resulting in habitat loss for the western skink (*P. skiltonianus*), the effectiveness of the use of different types of artificial cover to restore habitat is being studied (Dulisse and Boulanger 2008).

Cover modifies the thermal characteristics of the microhabitat, which may be important for thermoregulation. Like all reptiles, the overall health of the prairie skink depends on its ability to maintain a specific range of body temperatures to maximize behavioral and physiological processes, such as metabolism, locomotion, growth, and digestion (Huey and Slatkin 1976). Related species in the Plestiodon genus select microhabitat based on its thermal characteristics. For example, *P. fasciatus* and *P. elegans* select microhabitats with thermal profiles that closely match their preferred temperatures (Quirt *et al.* 2006; Du *et al.* 2006). Preferred body temperature for prairie skinks has not been studied, but Pentacost (1974) found that preferred body temperatures of *P. laticeps* in the lab is not significantly different from the body temperatures of individuals caught in the field. Body temperatures were not taken in my study, but Nelson (1963) observed field body temperatures ranging from 22.4°C to 35°C, with a mean of 29.7°C (n=36). This can be used to infer preferred body temperature for this species. In my study, daytime temperatures under cover (mean 24.78°C ±0.30) at the occupied sites were significantly cooler than the temperatures taken in the open on the surface of the ground (28.02°C ±0.35). Both temperatures are within the range of body temperatures observed by Nelson (1963), but the surface temperature is closer to the mean preferred body temperature. This suggests that prairie skinks in my study area may have a different range of preferred body temperatures than those in Nelson's study or that prairie skinks are choosing to use cover for reasons other than thermoregulation.

Dietary requirements and predator avoidance may have a stronger influence on cover use than temperature. Artificial cover not only provides suitable microhabitat for prairie skinks, but also for their prey (Scott 2005), which includes crickets, grasshoppers and beetles (Breckenridge 1943, Nelson 1963). Pitt (2001) found a positive correlation between prairie skink density and arthropod density in Minnesota. This has also been observed with other lizard species such as the *Gongylomorphus* genus of skinks (Ross *et* *al.* 2008) and with *P. obsoletus* (Fitch 1955). Predator avoidance was more important than thermoregulation for microhabitat selection by *P. obsoletus* (Fitch 1955) and *L. lepida* (Diaz *et al.* 2006). Rock cover is the most important microhabitat feature in predicting the abundance of *L. lepida*, and individuals caught under cover had lower body temperatures than those caught in the open. My study did not take into account moisture, which has been shown to be an important microhabitat feature for nesting for this species. Laboratory studies of prairie skinks captured in Nebraska indicate that prairie skinks require specific substrate moisture for nesting (Somma and Fawcett 1989).

Management Recommendations

The presence of artificial cover plays an important role in prairie skink conservation in Manitoba. In areas where skinks are present or where records of past captures exist, land managers and owners should allow the refuse that has built up on the landscape over the years to remain undisturbed on the land, when possible. Areas of importance include scrap metal dumps, refuse piles, fence lines with old fence posts and aluminium signs lying on the ground, old railway ties left along the railway tracks, and currently inhabited and abandoned farm yards. Leaving this garbage on the landscape may seem counter-intuitive, especially in parks and wildlife management areas; however, this refuse provides microhabitat for prairie skinks and possibly other reptiles in Manitoba.

I also recommend that land owners and managers in southwestern Manitoba use artificial cover in areas that are under pressure from habitat loss by aspen encroachment, leafy spurge invasion or development. This will create suitable microhabitat, provide refuge from predators, increase prey abundance, provide suitable nesting sites, and provide a substrate for thermoregulation. These artificial refuge sites should consist of a variety of types, sizes, and thicknesses of artificial cover in close proximity. This will provide a variety of different microhabitat conditions within a prairie skink's home range, allowing individuals to move between different pieces of cover when environmental conditions change. For example, an individual could take refuge under a thin piece of metal (which is a good heat conductor) for thermoregulation in the morning when the ambient temperature is cool. In the afternoon, when the ambient temperature rises, a thick piece of wood could allow the prairie skink to thermoregulate and achieve a body temperature lower than the ambient temperature.

Prairie skink artificial refuge sites could be used to provide suitable prairie skink microhabitat until habitat loss can be managed. Often land management regimes, such as controlled burns to prevent aspen encroachment or biocontrol of exotic species, require many resources and take time. The creation of prairie skink conservation sites is simple and inexpensive, and the artificial cover is often colonized quite quickly. In places frequented by the public, these prairie skink refuge sites may be visually unappealing; however, this can be mitigated with appropriate signage identifying the area as a prairie skink conservation site created to improve microhabitat.

My study demonstrated the importance of artificial cover, but did not examine the effectiveness of different types of cover. Bredin (1999) has used a variety of different artificial cover, and found that wood is the preferred cover type, with tin as a second choice, over cardboard, garbage bags, and burlap. Further investigation in artificial cover type preferences, including cover dimensions, thicknesses and type used is necessary in the design of future prairie skink conservation sites.

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Table 1. Categories of microhabitat elements used to compare occupied and unoccupied sites (modified from Howes and Lougheed 2004).

Microhabitat element	**Definition**
Artificial cover	Any piece of artificial cover made of wood, plastic, metal, carpet, fabric, brick or any other material laying on the ground
Soil	Exposed soil with no vegetation or leaf debris
Gravel	Exposed gravel from a road or rail bed with no vegetation or leaf debris
Juniper	Any part of a living juniper
Leaf litter	Broadleaf debris
Woody debris	Any deadfall or wood debris
Vegetation	Living or dead grass, herbaceous species and low shrubs

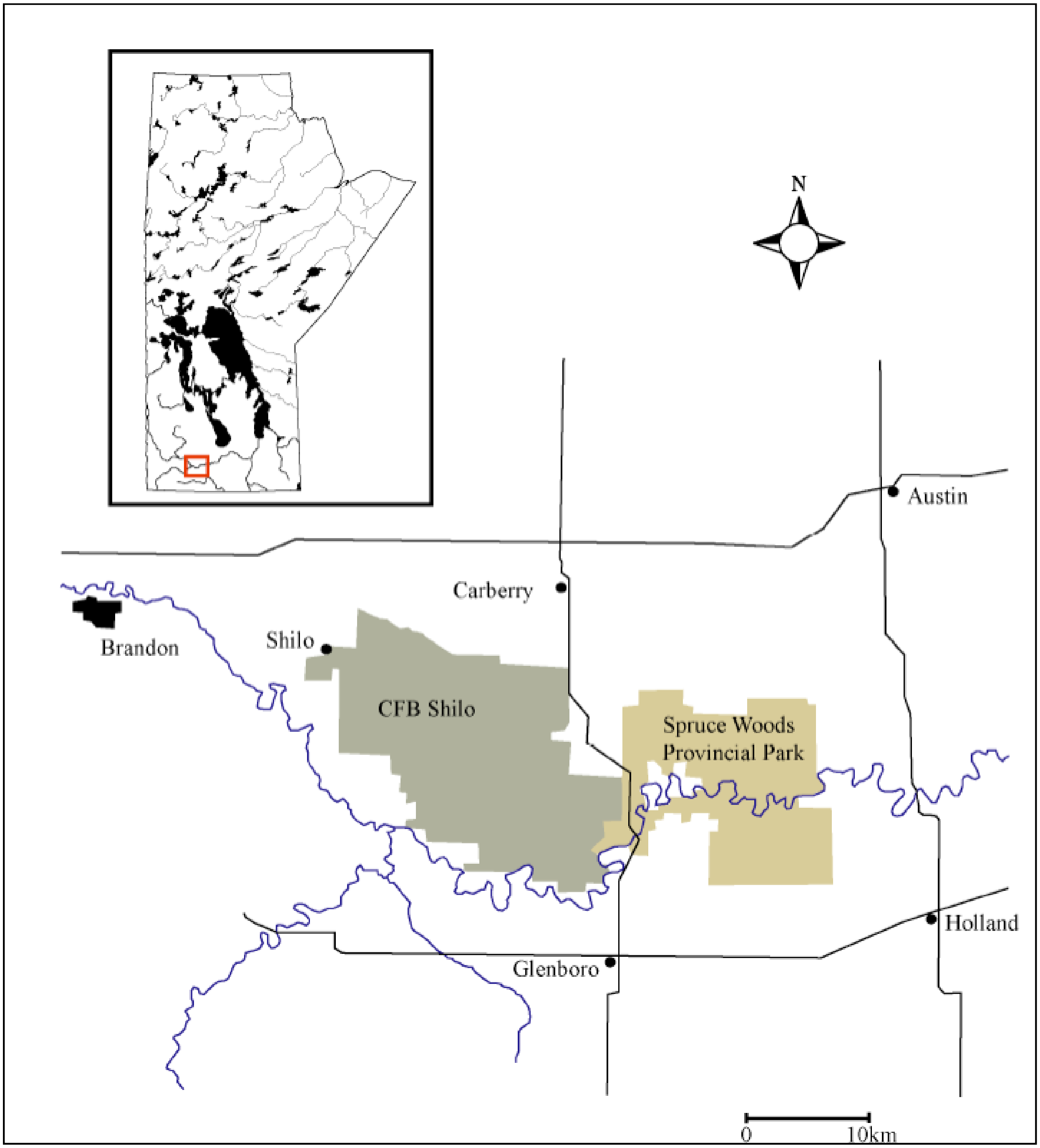

Figure 1. Study area consisted of Canadian Forces Base Shilo, Spruce Woods Provincial Park and the surrounding area in southwestern Manitoba (Source: Scott 2005).

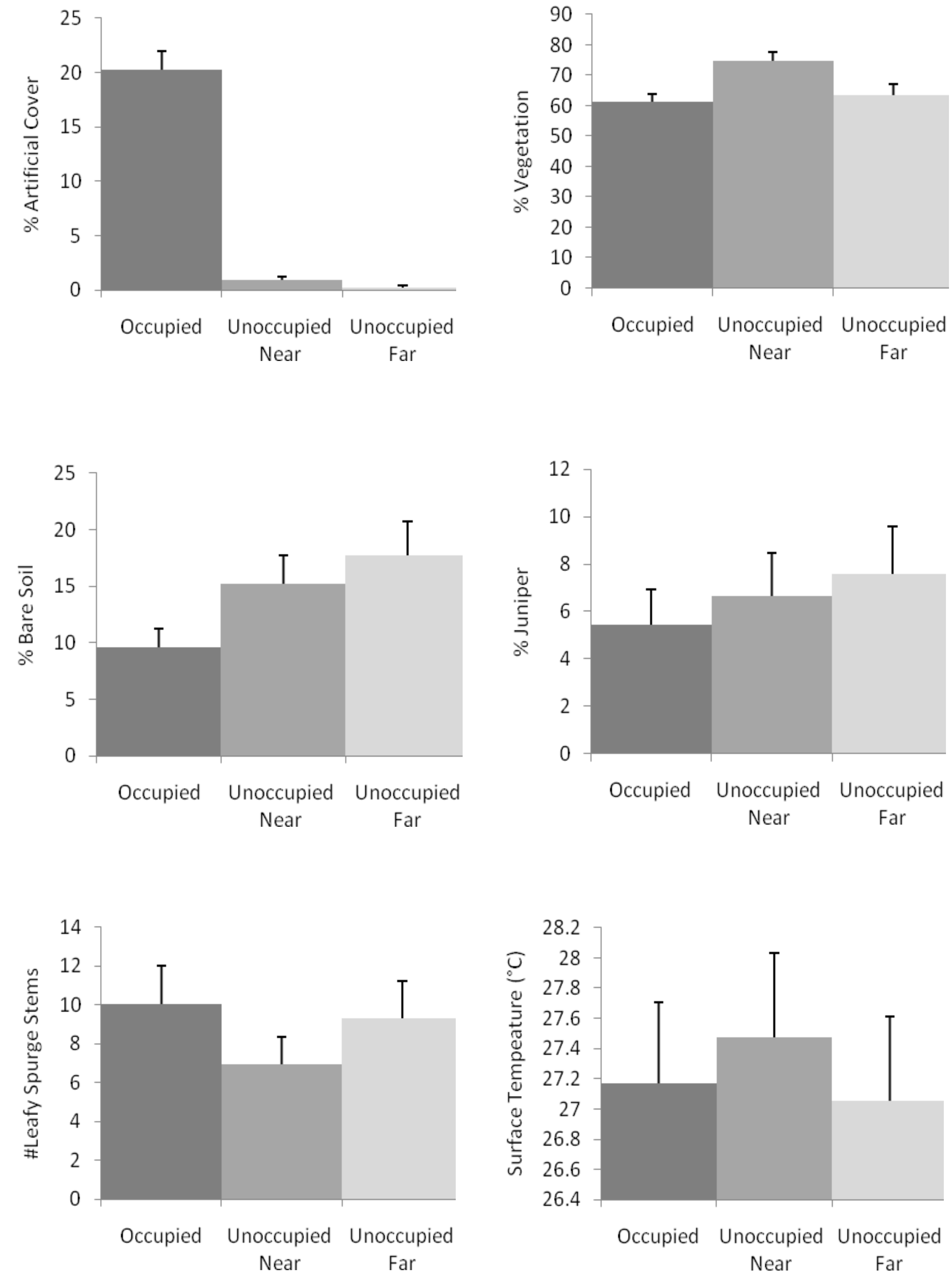

Figure 2. Mean percent cover for microhabitat elements in occupied, unoccupied near and unoccupied far sites.

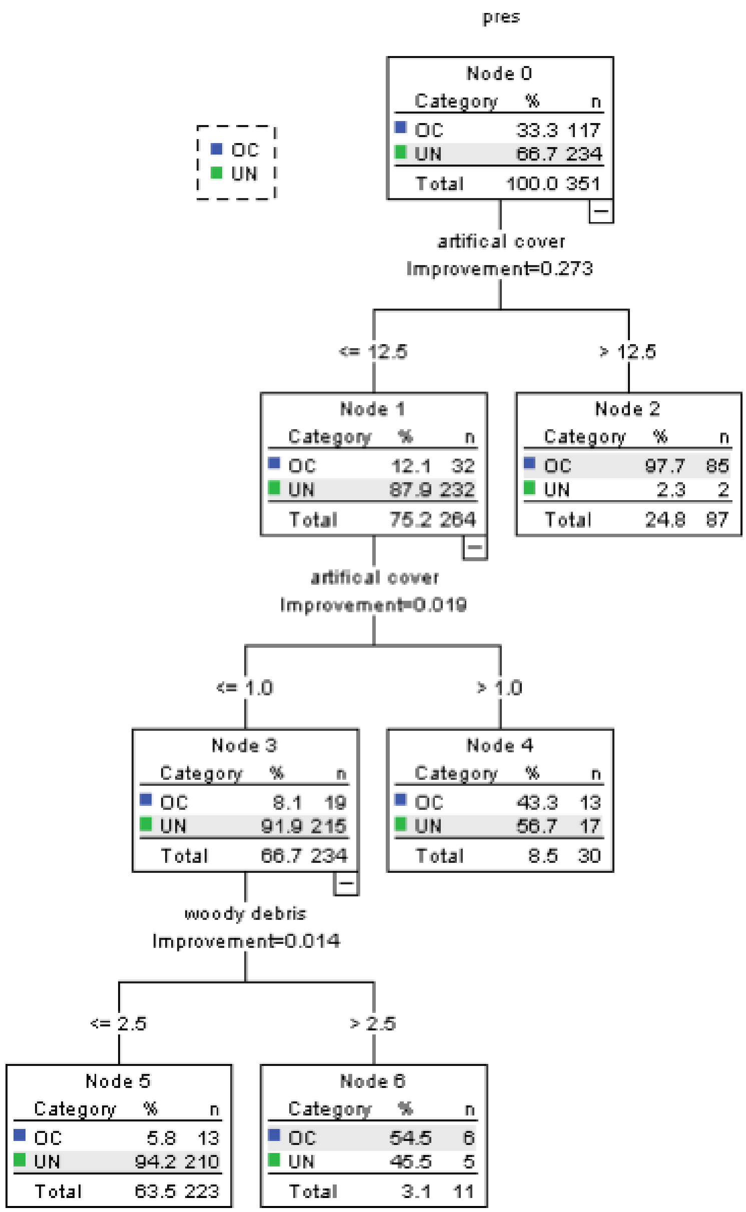

Figure 3. Classification and Regression Tree analysis (CART) for all captures (parent node 20, child node 10) comparing occupied sites (OC) and unoccupied sites (UN). Improvement refers to how the homogeneity of the groups improves as a result of each split in the dataset. Overall 90.6% of the sites were correctly classified.

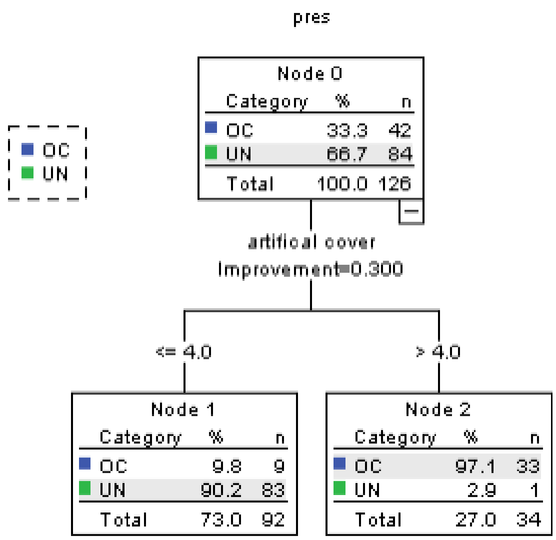

Figure 4. Classification and Regression Tree analysis (CART) for female skinks (parent node 20, child node 10) comparing occupied sites (OC) and unoccupied sites (UN). Improvement refers to how the homogeneity of the groups improves as a result of each split in the dataset. Overall 92.1% of the sites were correctly classified.

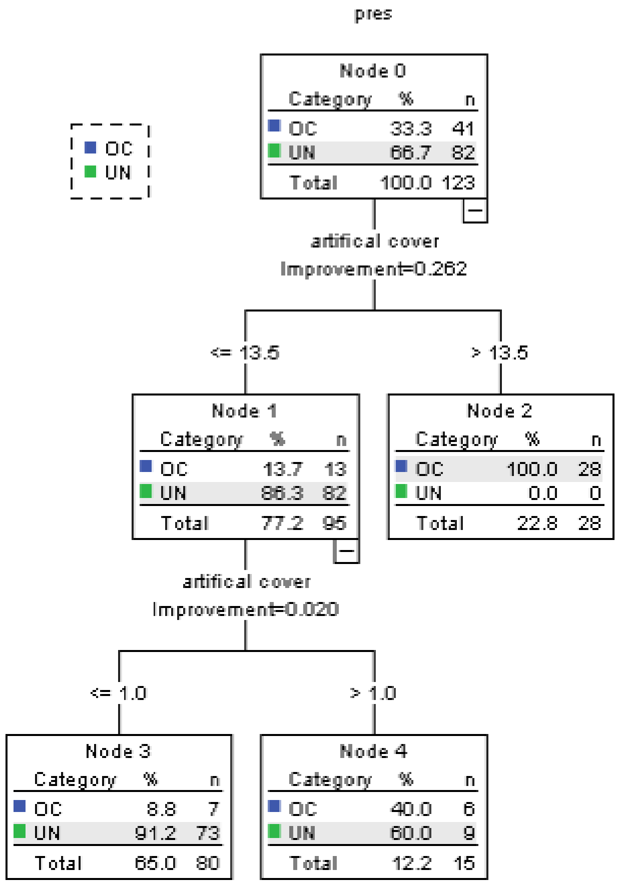

Figure 5. Classification and Regression Tree analysis (CART) for male skinks (parent node 20, child node 10), comparing occupied sites (OC) and unoccupied sites (UN). Improvement refers to how the homogeneity of the groups improves as a result of each split in the dataset. Overall 89.4% of the sites were correctly classified.

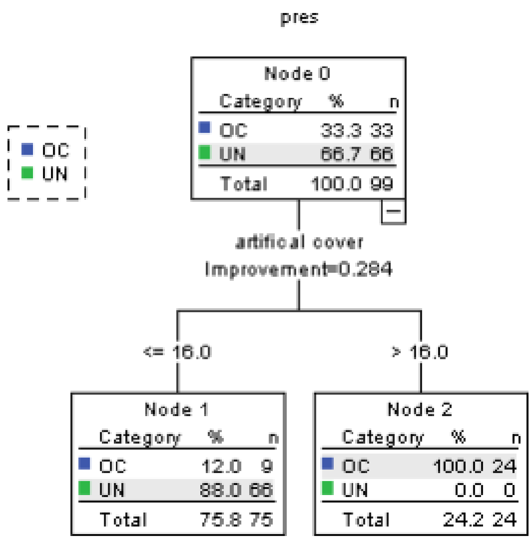

Figure 6. Classification and Regression Tree analysis (CART) for juvenile skinks (parent node 20, child node 10) comparing occupied sites (OC) and unoccupied sites (UN). Improvement refers to how the homogeneity of the groups improves as a result of each split in the dataset. Overall 90.9% of the sites were correctly classified.

CHAPTER 3: EFFECTS OF LEAFY SPURGE (*EUPHORBIA ESULA*) ON PRAIRIE SKINKS (*PLESTIODON SEPTENTRIONALIS*) IN SOUTHWESTERN MANITOBA

Abstract

In Canada, the prairie skink (*Plestiodon septentrionalis,* formerly *Eumeces septentrionalis*) exists only in southwestern Manitoba and is listed as Endangered under the Canadian Species at Risk Act. Habitat loss is the most significant threat faced by the prairie skink in Canada. Factors identified by COSEWIC (2004) contributing to habitat loss include: native prairie cultivation, aspen (*Populus tremuloides*) encroachment, leafy spurge (*Euphorbia esula*) invasion, urbanization and road construction. The objective of this study was to determine the impacts of leafy spurge on the thermal characteristics of the microhabitat and prairie skink density, and to examine the importance of cover in leafy-spurge-invaded habitat compared to un-invaded habitat. I used iButton ® data loggers to compare differences in daily standard deviation, maximum and mean ground temperatures between leafy-spurge invaded and un-invaded plots at four study sites. No significant differences in temperature were observed between leafy-spurge-invaded and un-invaded plots. Using coverboard sampling, no detectable differences in prairie skink densities between leafy-spurge-invaded and un-invaded plots were observed. However, an alternative analysis indicated that prairie skinks were significantly more likely to be found in leafy spurge patches when cover is present, than when no cover was present. Artificial cover may improve leafy-spurge-invaded prairie skink microhabitat by altering the thermal characteristics, providing refuge from predators, and providing microhabitat

for prairie skinks prey. Land managers should provide artificial cover in leafy spurge-invaded habitats for prairie skink conservation in southwestern Manitoba.

Introduction

The rapid spread of the exotic forb leafy spurge (*Euphorbia esula*) has had negative economic and ecological consequences across the great plains of North America (Thompson et al. 1990; Wallace *et al*. 1992; Bangsund *et al*. 1993). Leafy spurge invasion reduces livestock carrying capacity because it is unpalatable to cattle (Lym and Messersmith 1985). Leafy spurge invasion also decreases native plant species abundance (Belcher and Wilson 1989); and plant species richness (Butler and Cogan 2004; Larson and Larson 2010). Leafy spurge also negatively influences native songbird communities. For example, Scheiman *et al.* (2003) observed fewer nests and nesting species in plots with high leafy spurge invasion, which was attributed to the alteration of the structure of the habitat by leafy spurge. Wilson and Belcher (1989) found significant differences in native songbird species composition between native prairie and prairie invaded with leafy spurge, smooth brome (*Bromus inermis*) and Kentucky blue-grass *(Poa pratensis*), possibly due to associated changes in habitat structure and food availability. This demonstrates that leafy spurge invasion has ecologically relevant environmental impacts, and thus it might also influence prairie skinks, as well as other species such as songbirds.

Leafy spurge is a deep-rooted perennial, and grows in dense patches up to one metre tall (Lym 1998). This plant spreads rapidly through vegetative reproduction and is adapted to a wide variety of conditions, giving it vigorous competitive ability over native species

(Selleck *et al.* 1962, Messersmith *et al.* 1985). Vegetative reproduction occurs through buds on the roots and crown of the plant, which survive the winter under the soil (Messersmith *et al.* 1985). The annual mean rate of spread of this species in native grasslands is 0.64m per year (Selleck *et al*. 1962). Leafy spurge also has allelopathic properties, which allows it to inhibit the growth of other plant species and grow into homogeneous patches (Steenhagen and Zimdahl 1979). Due to the well-developed root system, it is very difficult to remove and control (Messersmith *et al.* 1985; Lym 1998).

Although no empirical data are available to evaluate this, leafy spurge invasion has been hypothesized as one of the suspected causes of the decline of the prairie skink (*Plestiodon septentrionalis*), a federally Endangered lizard that occurs in southwestern Manitoba (COSEWIC 2004). Lizards are greatly influenced by the physical structure of the vegetation and require heterogeneity within their environment (Pianka 1998; Jellinek *et al.* 2004); therefore, habitat availability may be compromised by the occurrence of homogeneous patches of leafy spurge. Changes in habitat structure also can alter the thermal characteristics of the microhabitat (Ehrenfeld 2010). Cool-climate reptiles, such as prairie skinks, are particularly susceptible to changes in vegetation structure, as their fitness is directly influenced by the thermal regimes of the microhabitat (Huey and Slatkin 1976). Individuals select microhabitats that allow them to maximize fitness by maintaining optimal body temperatures (Huey and Kingsolver 1989). A certain range of body temperatures must be maintained to maximize behavioral and physiological processes, such as metabolism, locomotion, growth, digestion and reproduction (Huey and Slatkin 1976; Huey 1991). Reptiles benefit from heterogeneity in their microhabitats because it allows them to behaviourally adjust their body temperature over a considerable thermal range to maintain optimal body temperatures (Huey 1974; Shine 2006).

Although no previous studies have been conducted to determine the effects of leafy spurge on reptile habitat use, there are many examples of the impacts of other invasive plants on lizard species in Australia. For example, lizards avoid non-native rubber vine habitat (Valentine 2006). Native habitat was selected over rubber vine habitat because native leaf litter had higher temperatures, higher abundance and diversity of prey, and larger leaves, which provided refuge from predators (Valentine *et al.* 2007). Lizards were also less abundant in habitat invaded by the introduced shrub *Mimosa pigra* (Braithwaite *et al*. 1989). Another study found that lizard species diversity was negatively related to the percent cover of exotic species (Smith *et al*. 1996). Exotic species invasion could potentially result in the local extinction of some lizard species (Jellinek *et al.* 2004).

Habitat loss is the most significant threat faced by the prairie skink in Canada. In addition to leafy spurge invasion, other factors contributing to habitat loss include native prairie cultivation, aspen (*Populus tremuloides*) encroachment, urbanization, and road construction. Low population density, limited dispersal, and low reproductive rates make this species vulnerable to extinction (COSEWIC 2004). Since prairie skinks are poor dispersers, there is little possibility of rescue effect from the US population, which occurs more than 150 km to the south (COSEWIC 2004). One of the main goals identified in the recovery strategy and action plan for prairie skinks was to protect and restore habitat to maintain self-sufficient populations. The purpose of my study was to determine the effect of leafy spurge invasion on prairie skinks and the thermal conditions of their microhabitat. Temperature profiles of leafy-spurge-invaded plots were compared with adjacent un-invaded plots. Coverboard sampling was used to compare prairie skink density in the leafy-spurge-invaded plots and adjacent un-invaded plots. Patch sampling was used to determine if prairie skinks were more likely to use leafy spurge patches if cover was present. This study provided valuable information that can be used by land managers to mitigate the potential negative effects of leafy spurge on prairie skink habitat. These results can be incorporated into the Prairie Skink Recovery Strategy and will be valuable in the conservation of this species in Canada.

Methods

Study Area

The study area is located within the Assiniboine River Delta, near Carberry (49°52’N, 99°21’W) in southwestern Manitoba (Figure 1). The Assiniboine River Delta is characterized by Stockton association soils developed on deep sandy deltaic deposits with surface textures varying between sand to very fine sandy loam (Schykulski and Moore 2000). These sands were deposited 11,000 years ago and were shaped into sandhills by eolian activity (Upham 1895). The majority of the sandhills have since been stabilized by grassland, aspen parkland, and forest communities (Bird 1927; Wolfe *et al.* 2000).

The vegetation community of the study area is unique because it is located in the transition zone between prairie and deciduous forest types, and also includes boreal forest remnants. Five distinct vegetation communities have been identified in the area, including sand plain, prairie, deciduous forest, mixed forest, and larch swamp (Bird

1927). The sand plain community consists of bare sand interspersed with isolated individuals and clumps of vegetation. The prairie community is dominated by grasses, with sedges and flowering plants. Lichens grow in sandier regions of the prairies and the knolls are covered with *Juniper horizontalis*. The deciduous forest community is dominated by trembling aspen (*Populus tremuloides*), with the exception of wetter areas where balsam poplar (*Populus balsamifera*) and bur oak forest (*Quercus macrocarpa*) dominate. The mixed forest community is composed of white spruce (*Picea glauca*), trembling aspen, bur oak, and willow. The larch swamp community is dominated by tamarack (*Larix laricina)* and dwarf birch (*Betula glandulosa).* Prairie skinks have been observed in all five vegetation communities to varying extents.

The vegetation cover in the study area has changed dramatically in the past 150 years (Schykulski and Moore 2000). Three major changes have been observed: 1) the vegetation cover has increased resulting in the stabilization of the sand dunes, 2) the amount of prairie has decreased due to the encroachment of woody vegetation, and 3) the exotic invasive plant, leafy spurge, has taken over many areas of mixed-grass prairie aggressively out-competing native species.

The study area lies within the subhumid climatic zone (Wolfe *et al*. 2000). According to long-term weather data (1971-2000) collected at the nearest Environment Canada weather station (Brandon Airport), located approximately 30 km west of the study area, the mean monthly temperatures ranged from 18.4ºC in July to -18.0ºC in January (Environment Canada). Average daily maximum from May to September ranged from

16.1ºC to 24.9ºC. Average daily minimums during this time ranged from 2.6ºC to 12.9ºC. July was the warmest month, with a mean monthly temperature of 18.9ºC. During this same time frame (1971-2000) the average total annual precipitation was 472 mm. Of this precipitation, 373 mm fell as rain, and 112 mm fell as snow. The annual peak in precipitation occurred in July, with an average precipitation of 76 mm.

My study was located within Canadian Forces Base Shilo (CFB Shilo) and Spruce Woods Provincial Park. Primary land uses in this area include agriculture, military training activity, recreation and conservation. The two largest communities in the area include Carberry (population=1,502), and Glenboro (population=633; Statistics Canada 2006). Over the last two decades there has been an increase in agricultural activities in the areas surrounding CFB Shilo and Spruce Woods Provincial Park. This includes an increase in the number of large livestock operations (especially large scale hog barns) and potato farming (Assiniboine Aquifer Delta Round Table 2005). The annual number of visitors to Spruce Woods Provincial Park is between 60,000 and 100,000 individuals (Madelyn Robinson, personal communication).

Effects of leafy spurge on the thermal characteristics of microhabitat

To determine the effects of leafy spurge on the thermal characteristics of prairie skink microhabitat, four study sites were used: three in CFB Shilo (Firetower-FT, Sawyer-SA, Onah-ON) and one in Spruce Woods Provincial Park (Yellowquill-YQ; Figure 2). At each site, three subsites were established, each consisting of a leafy-spurge-invaded plot (treatment) paired with an adjacent un-invaded plot (control). The paired treatment and control plots were located between 5 m and 10 m apart from each other. Both plots were placed within the home range of a prairie skink to allow individuals the option of moving between the treatment-control pairs to select the preferred microhabitat. Nelson (1963) estimated that the home range size of *P. septentrionalis* is between 30 m and 100 m in diameter. Scott (2005) observed total movements of up to 16 m, with an average of 5.37 m per 4 hour period. A conservative estimate for prairie skink movement (within 10 m) was used in this study to ensure that both plots were within the home range of the individual.

On a bi-weekly basis, the un-invaded plots were checked for new growth of leafy spurge. If spurge was found, the stems were removed by cutting them at the base of the plant at the surface of the ground.

Temperatures were recorded using a thermal data logger (iButton ®, produced by Maxim), a quarter-sized device that can be programmed to regularly record temperatures at desired intervals. An iButton ® set to take a temperature reading every hour was placed in the centre of each plot two centimeters below the surface. Each iButton ® was attached to a wooden stick and covered with two small Ziploc ® bags, to protect the devices from the elements. The iButtons were deployed on July 3, 2008 and removed on September 3, 2008.

Differences in daily standard deviation, maximum and mean temperatures between leafy-spurge-invaded plots and adjacent un-invaded plots were statistically analyzed using Generalized Estimating Equations (GEE) analyses in PASW 18 Statistics software. This method was chosen because it can compensate for the lack of independence of data points. Four different models were run to determine which correlation structure best fit the data. The first model assumed the data were independent. The second assumed that the data were compound symmetric, with data being correlated within each site. The third model assumed that the data were compound symmetric, with data being correlated within each logger. The last model assumed that the data were auto-correlated within each logger, meaning that readings taken closer together in time were more similar than those taken further apart. For each model, the standard error of the empirical model was compared with the standard error of the model-based estimator and the model with the ratio closest to one was considered the best model (Koper and Manseau 2009).

After the GEEs were run with the entire dataset, the data for each site was analyzed individually, excluding the FT site. Due to failed iButtons, there were insufficient data to run the analysis for the FT data because there was only one successful treatment and control pair. Only three models were tested with the site data; the compound symmetric model testing for correlation between loggers at the same sites was not run because there was only one site in this analysis.

Effects of leafy spurge on prairie skink density

Coverboard sampling was used to determine the effects of leafy spurge on prairie skink density. This method is commonly used for capturing reptiles (Mushinsky 1992; Seburn 1993; Metts *et al.* 2001) and has been proven effective for prairie skinks (Bredin 1999; Fuerst and Austin 2004; Scott 2005). Coverboard sampling involves placing a standardized number of artificial cover objects of specific dimensions in the field with the object of capturing reptiles. Since wood is the most effective material for attracting prairie skinks (Bredin 1999), ¾ inch plywood was used for coverboards.

In May 2008, ten 30 cm by 60 cm plywood coverboards were randomly placed in a cluster (4 m diameter) at each of the leafy-spurge-invaded and un-invaded plots at each of the three subsites located within the four study sites (FT, SA,YQ, ON). The coverboards were checked on a bi-weekly basis. All individuals found under the coverboards were captured by hand, marked by toe clipping with a unique identification, and released at the point of capture. The number of individuals caught at each leafy-spurge-invaded plot (treatment) was compared with each adjacent un-invaded plot (control). To minimize bias, the capture data were examined and if an individual was caught more than once under the same board in consecutive bi-weekly checks, only the first observation was used in the analysis. Prairie skinks have very small home ranges and individuals may remain under the same piece of cover for extended periods of time (COSEWIC 2004). If the individual was caught under the same coverboard in consecutive bi-weekly checks, it is possible that the individual had not moved from the board since the previous check. This would mean that the observations are not independent. However, if the individual was caught once under a particular board then not present on the next check month or more later, I assumed that represented an independent microhabitat selection.

To determine if there was a significant difference in the number of skinks captured in treatment plots compared to control plots, a multi-way ANOVA was used. The variables used in the ANOVA included site, treatment (leafy spurge invaded vs un-invaded) and an interaction between the two variables. Site was included in the model to control for the variation introduced by the sites.

Use of cover by skinks in leafy spurge patches vs un-invaded habitat

To determine if prairie skinks are more likely to use leafy spurge patches if cover is present than leafy spurge with no cover present, a Chi-squared analysis was used. Skinks were caught by coverboard sampling, patch sampling and pedestrian sampling throughout my study area in 2007 and 2008. Patch sampling involves systematically turning over all natural and artificial cover within a defined area (Bredin 1999). Pedestrian sampling involves walking through areas of potential habitat in attempt to flush up a skink (Nelson 1963). All animals were captured by hand, marked, and released at the point of capture, as described above. For each capture, the first and second most dominant plant species were recorded. I also recorded whether or not the individual was caught under cover or in the open. Cover refers to artificial (plywood, tin, brick or other debris) or natural (log or woody debris) cover.

Each observation (skink capture) was classed into one of four groups: spurge-open, spurge-cover, no spurge-open, or no spurge-cover. If leafy spurge was identified as either the first or second most dominant plant, the observation was placed in a spurge group. I predicted that the ratio of the captures in the open to the captures under cover would be similar in spurge-invaded and un-invaded areas. The analysis was run three times, first with the data from both years pooled and once for each year separately.

All statistical analyses were performed using PASW 18 Statistics software (formerly SPSS Statistics).

Results

Effects of leafy spurge on microhabitat

When the GEE analysis was run using the entire dataset, the best model for the daily standard deviation, maximum and mean temperatures based on the ratio of model standard error to the empirical standard error was the compound symmetric model, with correlation within each logger (Table 1A); therefore, this was the model used for all subsequent analyses. There were no significant differences in daily standard deviation (p=0.97, SE=0.35), maximum (p=0.98, SE=1.15) or mean (p=0.92, SE=0.57) temperatures between invaded and un-invaded plots. When the sites were analyzed individually, the compound symmetric model, with correlation within each logger was also the best model for the daily standard deviation, maximum and mean temperatures at YQ and SA. No significant differences in mean, maximum or standard deviation temperature were observed at YQ and SA (Table 1B and C). At ON, the best model for the daily standard deviation in temperature was the autoregressive model. For the daily maximum and mean temperatures, the compound symmetric model with correlation within each logger was the best model. At ON the daily standard deviation ($p<0.001$, SE=0.13), maximum ($p<0.001$, SE=0.072) and mean ($p<0.001$, SE=0.17) temperatures were significantly higher in the leafy spurge invaded plots than un-invaded plots (Table 1D).

Effects of leafy spurge on prairie skink density

The interaction between site and treatment in the multi-way ANOVA was not significant ($F_{3,16}$=0.251, p=0.859); therefore, this term was removed from the analysis. When the main effects were tested, no significant difference in the number of skinks was observed between the treatment and control plots ($F_{1,19}$=0.98, p=0.34), but skink density varied by site ($F_{3,19}$=8.933, p=0.001, Figure 3).

Use of cover by skinks in leafy spurge patches vs un-invaded habitat

When data were pooled over years 2007 and 2008, 94.5% of the skinks observed in the leafy spurge were observed under cover, compared to 74.0% of the individuals observed under cover in un-invaded areas (n = 496; Chi-square = 14.82, df = 1, $p < 0.001$). Significant differences in the expected versus the observed values were also observed when the data from each year were analyzed separately (2007: Chi-square = 12.51, df = 1, $p < 0.001$; 2008: Chi-square = 4.17, df = 1, $p < 0.001$; Table 2).

There are limitations to the results of the Chi-squared analysis because the ratio of the area invaded by leafy spurge to un-invaded habitat was not quantified. In addition, the amount of cover available within each these habitats is unknown. Cover use may be influenced by the amount of cover available in each habitat. For example, if was more cover was available in leafy spurge invaded areas than un-invaded areas, it is possible that there could be more skinks caught under cover in leafy spurge invaded habitat, than in un-invaded habitat.

Discussion

My results indicate that leafy spurge does not have a significant influence on the thermal regime of the microhabitat, and nor does it affect prairie skink occurrence under coverboards. This suggests that leafy spurge invaded sites are not avoided by prairie skinks as previously thought by COSEWIC (2004). However, the results of the Chi-squared analysis indicate that prairie skinks might be more dependent on cover in leafy spurge invaded areas than in un-invaded areas. I caution that the result of the Chi-saured test may be biased because I did not control for the amount of cover present on the landscape in leafy spurge invaded and un-invaded habitats.

It is possible that the addition of coverboards makes the leafy spurge patches more suitable for skinks. For example, coverboards alter the thermal conditions of the microhabitat by moderating the temperature and making the temperature cooler than the ambient temperature (Engelstoft and Ovaska 2000). Cover is also important for nesting (Fitch 1955; Breckenridge 1943; Bredin 1989; Hecnar 1994), feeding (Fitch 1955; Scott 2005) and predator avoidance (Fitch 1955; Seburn 1993). These aspects of cover were not investigated in this study.

The lack of our ability to detect a difference in prairie skink density between invaded and un-invaded sites may be attributed to the fact that coverboard sampling may not provide an accurate reflection of prairie skink density. The use of coverboards by prairie skinks in habitat that was considered unsuitable has also been observed in other studies. Perhaps similarly, Scott (2005) found skinks in shrub cover, which is typically considered unsuitable habitat (Bredin 1989). There could be two explanations: 1) the habitat that was thought to be unsuitable is actually suitable, or 2) the coverboards modified unsuitable habitat, making it suitable for skinks. Scott dismissed the second possibility based on the assumption that skinks were already in this area, just previously not detected. She did not suspect that a skink would travel 2m through unsuitable habitat seeking a coverboard. Although skinks typically have very small home ranges (Bredin 1988), I disagree with Scott's conclusion, and assume that a prairie skink could travel 2m through unsuitable habitat to seek shelter. Moving this distance is not unreasonable, since Nelson (1963) estimated that the home range size of *P. septentrionalis* is between 30 m and 115 m in diameter. Scott (2005) observed total movements of up to 16 m, with an average of 5.37 m per 4 hour period. Bredin (1988) observed the movement of a group of marked individuals from an area that became invaded by leafy spurge to an un-invaded area located 60m away, over a 5 year period. In my study, the leafy-spurge-invaded and un-invaded plots were located less than 10m apart, which is well within the home range. This distance was chosen to allow the individuals the option of moving between the two plots to select the most suitable microhabitat.

Bredin (1988) suggests that leafy spurge patches are avoided by skinks because they have lower insect abundance, but insect abundance in leafy spurge invaded versus native habitats has never been studied. However, since leafy spurge tends to out-compete native vegetation, reducing plant species diversity (Belcher and Wilson 1989; Butler and Cogan 2004; Butler *et al*. 2006), which is positively correlated with insect abundance (Haddad *et al*. 2001), leafy spurge invasion might result in decreased insect abundance. However, since prairie skink prey (crickets, beetles and grasshoppers) use coverboards (Scott 2005), the presence of coverboards may increase prey abundance in leafy spurge patches, which would increase prairie skink densities. Therefore, when I added coverboards to leafy-spurge-invaded patches, the coverboards modified the habitat, which may have attracted skinks to the leafy spurge patches.

Leafy spurge was patchy in the study area. There were various sizes of leafy spurge patches interspersed with un-invaded patches, with a gradient of partially invaded areas in between. Therefore, prairie skinks that are found in leafy spurge patches have the opportunity to use adjacent un-invaded and partially un-invaded areas. However, if leafy spurge is not controlled, the ratio of leafy-spurge-invaded to un-invaded area will increase. If there is no cover present in the leafy spurge patches, there may not be suitable microhabitat for prairie skinks. This could force skinks to use a larger area, which would require them to expend more energy, reducing fitness. Also, it is possible that large, dense patches of leafy spurge may act as barriers to dispersal, if no cover is present within the patches.

Currently, goat grazing and biocontrol methods are being used to control leafy spurge in the study area. The impacts of these practices on prairie skinks have not been studied. Cattle grazing has had positive effects on other lizard species. Fitch (1955) determined that grazing prevents the encroachment of deciduous forests, preventing habitat loss, which maintains *Eumeces obsoletus* population size. His study, which took place in Kansas, concluded that discontinuing grazing resulted in decreased skink population sizes. Ballinger and Watts (1995) observed similar results with other lizard species in a study in Nebraska. After grazing was suppressed, succession resulted in increased grass density and a reduction in bare sand areas. Lizard population density decreased as grass density increased. They predicted that if grazing is ceased, it is likely that these lizards would become extirpated. Jones (1981) found that the intensity of grazing had an impact on lizard density. Lightly grazed sites had higher densities of lizards than heavily grazed sites. When the structure of the vegetation was significantly altered by grazing, the density of lizards was significantly reduced. When the structure of the vegetation was not significantly affected by grazing, lizard density was not significantly affected. However, this study took place in Arizona, where the climate is much warmer. Therefore, it is possible that lizards in this study required higher densities of vegetation cover for optimal thermal conditions. The impacts of biocontrol on other lizard species have not been studied, however it is suspected that this practice will have not have negative effects on prairie skinks.

Management Recommendations

Since prairie skinks depend on cover in leafy spurge patches, I would recommend providing artificial cover within leafy spurge patches to provide microhabitat until the leafy spurge has been managed by goat grazing or biocontrol measures. Cover provides refuge from predators, increased prey abundance, suitable nesting sites, and a substrate for thermoregulation.

This study examined the impacts of leafy spurge on prairie skinks from a microhabitat scale. I would recommend examining the effects of leafy spurge on a landscape scale throughout the Manitoba range to determine if leafy spurge is influencing the Canadian population as a whole. I would suggest setting up a long-term monitoring program throughout the prairie skink`s Canadian range with monitoring sites on provincial, federal and private lands. A standardized protocol should be developed and followed, so the data can be compared between sites and over time. The spread of leafy spurge across the prairie skink`s Canadian range could be monitored using remote sensing techniques. This information could be used to determine if there is a correlation between prairie skink density and spurge invasion on a landscape scale.

Since goat grazing and biocontrol are being used to control leafy spurge within the range of the prairie skink in southwestern Manitoba, the impacts of these management practices on prairie skinks should be examined.

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Table 1A. Results from the Generalized Estimating Equation testing differences in daily standard deviation, maximum and mean temperatures in leafy spurge invaded (treatment) versus un-invaded (control) plots at all sites.

Measure	Model	Empirical SE	Model-Based SE	Ratio	p-value	Mean Control	SE	Mean Treatment	SE
Daily standard deviation	Independent	0.26	0.08	3.48	0.26	2.44	0.25	2.43	0.13
	Compound Symmetric 1	0.26	0.08	3.48	0.26	2.31	0.32	2.30	0.22
	Compound Symmetric 2	0.35	0.35	**1.00**	0.35	2.44	0.27	2.43	0.23
	Autoregressive	0.35	0.12	2.99	0.35	2.43	0.27	2.42	0.23
Daily Maximum	Independent	0.80	0.22	3.69	0.80	23.87	0.89	23.90	0.42
	Compound Symmetric 1	0.80	0.20	3.92	0.80	23.43	1.15	23.46	0.72
	Compound Symmetric 2	1.15	1.15	**1.00**	1.15	23.87	0.87	23.90	0.75
	Autoregressive	1.14	0.47	2.42	1.14	23.68	0.86	23.71	0.75
Daily Mean	Independent	0.46	0.12	3.66	0.46	20.01	0.50	19.95	0.26
	Compound Symmetric 1	0.46	0.34	1.35	0.46	19.82	0.62	19.76	0.38
	Compound Symmetric 2	0.57	0.57	**1.00**	0.57	20.01	0.44	19.95	0.36
	Autoregressive	0.56	0.30	1.84	0.56	19.82	0.44	19.77	0.35

Table 1B. Results from the Generalized Estimating Equation testing differences in daily standard deviation, maximum and mean temperatures in leafy spurge invaded (treatment) versus un-invaded (control) plots at Yellowquill.

Measure	Model	Empirical SE	Model-Based SE	Ratio	p-value	Mean Control	SE	Mean Treatment	SE
Daily standard deviation	Independent	0.45	0.13	3.33	0.45	0.45	2.83	0.44	2.33
	Compound Symmetric	0.45	0.66	**0.68**	0.45	0.45	2.83	0.44	2.33
	Autoregressive	0.66	0.23	2.90	0.45	0.45	2.81	0.16	2.32
Daily Maximum	Independent	2.04	0.38	5.42	0.51	0.51	24.92	1.16	23.56
	Compound Symmetric	2.04	2.04	**1.00**	0.51	0.51	24.92	1.16	23.56
	Autoregressive	2.02	0.83	2.43	0.52	0.52	24.69	1.14	23.37
Daily Mean	Independent	0.81	0.20	4.16	0.35	0.35	20.40	0.41	19.58
	Compound Symmetric	0.87	0.87	**1.00**	0.35	0.35	20.40	0.41	19.58
	Autoregressive	0.85	0.47	1.82	0.36	0.36	20.19	0.40	19.41

Table 1C. Results from the Generalized Estimating Equation testing differences in daily standard deviation, maximum and mean temperatures in leafy spurge invaded (treatment) versus un-invaded (control) plots at Sawyer.

Measure	Model	Empirical SE	Model-Based SE	Ratio	p-value	Mean Control	SE	Mean Treatment	SE
Daily standard deviation	Independent	0.58	0.14	4.04	0.58	2.82	0.25	2.59	0.32
	Compound Symmetric	0.58	0.41	**1.43**	0.58	2.82	0.25	2.59	0.32
	Autoregressive	0.41	0.18	2.25	0.58	2.81	0.25	2.59	0.32
Daily Maximum	Independent	1.19	0.40	2.95	0.42	25.81	0.83	24.85	0.85
	Compound Symmetric	1.19	1.19	**1.00**	0.42	25.81	0.83	24.85	0.85
	Autoregressive	1.18	0.66	1.79	0.41	25.72	0.47	24.75	0.47
Daily Mean	Independent	0.51	0.24	2.12	0.19	21.34	0.45	20.66	0.24
	Compound Symmetric	0.51	0.51	**1.00**	0.19	21.34	0.45	20.66	0.24
	Autoregressive	0.19	0.48	0.39	0.19	21.22	0.46	20.54	0.23

Table 1D. Results from the Generalized Estimating Equation testing differences in daily standard deviation, maximum and mean temperatures in leafy spurge invaded (treatment) versus un-invaded (control) plots at Onah.

Measure	Model	Empirical SE	Model-Based SE	Ratio	p-value	Mean Control	SE	Mean Treatment	SE
Daily Standard Deviation	Independent	0.13	0.12	1.08	<0.001	2.12	0.03	2.75	0.12
	Compound Symmetric	0.13	0.13	1.00	<0.001	2.12	0.03	2.75	0.12
	Autoregressive	0.13	0.13	**1.00***	<0.001	2.12	0.09	2.75	0.09
Daily Maximum	Independent	0.07	0.30	0.24	<0.001	22.58	0.04	24.54	0.06
	Compound Symmetric	0.07	0.08	**0.94**	<0.001	22.58	0.04	24.54	0.06
	Autoregressive	0.07	0.44	0.17	<0.001	22.52	0.04	24.48	0.06
Daily Mean	Independent	0.17	0.20	0.83	<0.001	19.23	0.08	20.26	0.15
	Compound Symmetric	0.17	0.17	**0.99**	<0.001	19.23	0.08	20.26	0.15
	Autoregressive	0.16	0.39	0.41	<0.001	19.13	0.28	20.17	0.08

*Prior to rounding, Autoregressive was closer to 1.00 than Compound Symmetric.

Table 2. Results from Chi-square comparing the ratio of skink captures in the open to captures under cover in leafy-spurge-invaded and un-invaded areas.

2007 and 2008		Cover	Open	Total
No Spurge	Count	313	110	423
	Expected Count	325.8	97.5	423
Spurge	Count	69	4	73
	Expected Count	56.2	16.8	73
Total	Count	382	114	496
	Expected Count	382	114	496

2007		Cover	Open	Total
No Spurge	Count	87	69	156
	Expected Count	95.1	60.9	156
Spurge	Count	24	2	26
	Expected Count	15.9	10.1	26
Total	Count	111	71	182
	Expected Count	111	71	182

2008		Cover	Open	Total
No Spurge	Count	226	41	267
	Expected Count	230.4	36.6	267
Spurge	Count	45	2	47
	Expected Count	40.6	6.4	47
Total	Count	271	43	314
	Expected Count	271	43	314

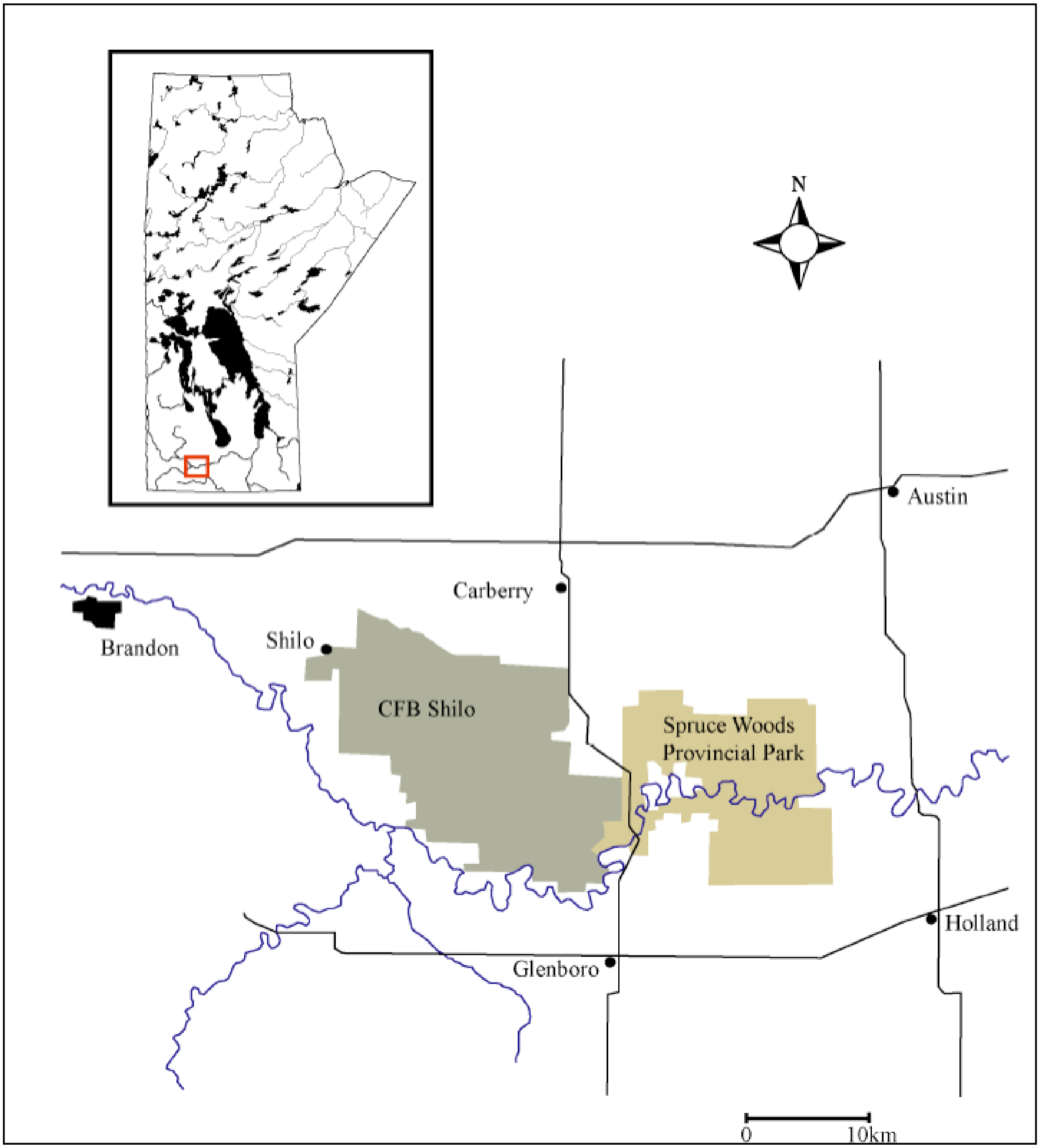

Figure 1. Study area consisted of CFB Shilo, Spruce Woods Provincial Park and the surrounding area in southwestern Manitoba (Source: Scott 2005).

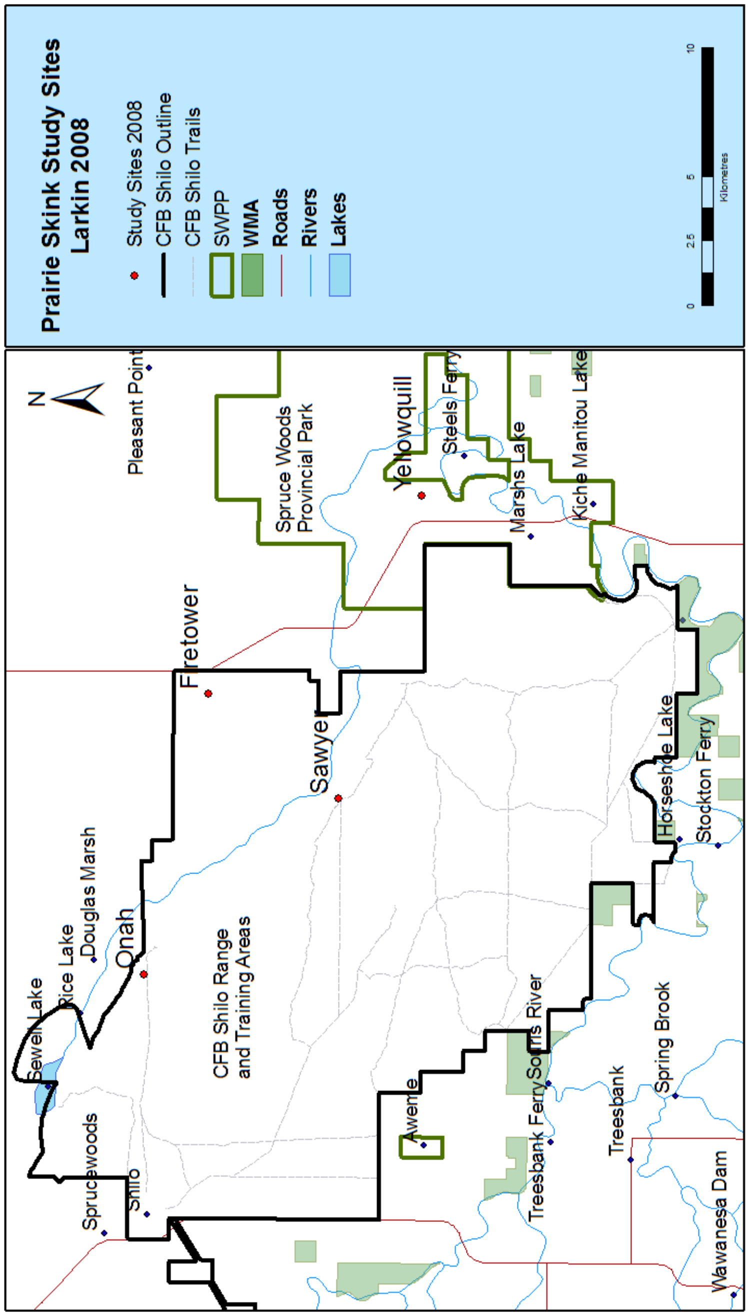

Figure 2. Study sites at CFB Shilo (CFB Shilo (Firetower-FT, Sawyer-SA, Onah-ON) and one in Spruce Woods Provincial Park (Yellowquill-YQ) in summer 2008.

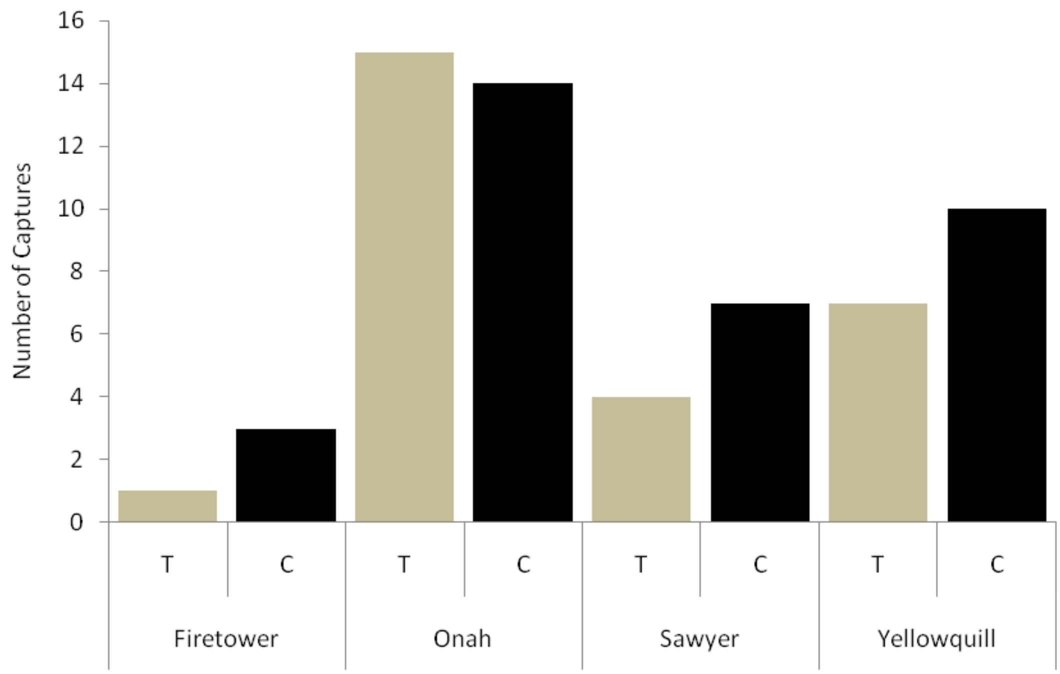

Figure 3. Number of skinks captured in leafy spurge *(Euphorbia eslua)* invaded (gray: treatment) and un-invaded plots (black: control) plots at each site by coverboard sampling.

CHAPTER 4: SUMMARY OF MANAGEMENT RECOMMENDATIONS

The presence of artificial cover plays an important role in prairie skink conservation in Manitoba. In areas where skinks are present or where records of past captures exist, land managers and owners should allow the refuse that has built up on the landscape over the years to remain undisturbed on the land, when possible. Areas of importance include scrap metal dumps, refuse piles, fence lines with old fence posts and aluminium signs lying on the ground, old railway ties left along the railway tracks, and currently inhabited and abandoned farm yards. Leaving this garbage on the landscape may seem counter-intuitive, especially in parks and wildlife management areas; however, this refuse provides microhabitat for prairie skinks and possibly other reptiles in Manitoba.

I also recommend that land owners and managers in southwestern Manitoba provide artificial cover in areas that are under pressure from habitat loss by aspen encroachment, leafy spurge invasion or development. This will create suitable microhabitat, provide refuge from predators, increase prey abundance, provide suitable nesting sites, and provide a substrate for thermoregulation. These artificial refuge sites should consist of a variety of types, sizes, and thicknesses of artificial cover in close proximity. This will provide a variety of different microhabitat conditions within a prairie skink’s home range, allowing individuals to move between different pieces of cover when environmental conditions change. For example, an individual could take refuge under a thin piece of metal (which is a good heat conductor) for thermoregulation in the morning when the ambient temperature is cool. In the afternoon, when the ambient temperature rises, a thick piece of wood could allow a prairie skink to thermoregulate and achieve a body temperature lower than the ambient temperature.

Prairie skink artificial refuge sites could be left on the landscape long term or temporarily to provide suitable prairie skink microhabitat until habitat loss can be managed. Often land management regimes, such as controlled burns to prevent aspen encroachment or biocontrol of exotic species, require many resources and take time. The creation of prairie skink conservation sites is simple and inexpensive, and the artificial cover is often colonized quite quickly (i.e. within weeks, if skinks are present in the area). In places frequented by the public, these prairie skink refuge sites may be visually unappealing; however, this can be mitigated with appropriate signage identifying the area as a prairie skink conservation site created to improve microhabitat.

My study demonstrated the importance of artificial cover, but did not examine the effectiveness of different types of cover. Bredin (1999) tested a variety of different artificial cover, and found that wood is the preferred cover type, with tin as a second choice, over cardboard, garbage bags, and burlap. Further investigation in artificial cover type preferences, including cover dimensions, thicknesses and type used is necessary in the design of future prairie skink conservation sites.

This study examined the impacts of leafy spurge on prairie skinks from a microhabitat scale. I would recommend examining the effects of leafy spurge on a landscape scale throughout the Manitoba range to determine if leafy spurge is influencing the Canadian population as a whole. I suggest setting up a long-term monitoring program throughout the prairie skink`s Canadian range with monitoring sites on provincial, federal and private lands. A standardized protocol should be developed and followed, so the data can be compared between sites and over time. The spread of leafy spurge across the prairie skink`s Canadian range should be monitored using remote sensing techniques. This information could be used to determine if there is a correlation between prairie skink density and spurge invasion on a landscape scale.

Since goat grazing and biocontrol are being used to control leafy spurge within the range of the prairie skink in southwestern Manitoba, the impacts of these management practices on prairie skinks should be examined.