Please note that location information has been removed from this document to protect sensitive species' populations.

Microhabitat Components of Key Habitat Types in the Anoka Sand Plain that Influence Habitat Selection among Species in Greatest Conservation Need

MN T-24-R-1

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Division of Ecological and Water Resources

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March 2012

The artists above are two volunteers on this project who produced original hognose snake art in response to their experiences in the field.

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Introduction and Background

The upland habitats (including oak woodland, oak savanna, prairie, grassland, and dune) in the Anoka Sand Plain subsection are being developed at an accelerating rate. The main portion of this subsection stretches across the northern portion of the Twin Cities metropolitan area, west to the St. Cloud area, and north to the North Branch area (Figure 1). Human population growth in the Anoka Sand Plain is the second fastest of any subsection in the state, and more than 90% of the land is in private ownership (MN DNR, 2006). Loss and degradation of habitat are the most significant challenges facing Species in Greatest Conservation Need (SGCN) populations in this subsection (MN DNR, 2006). Oak savanna, prairie, grasslands and dunes are designated as key habitats in Minnesota's State Wildlife Action Plan (SWAP) (MN DNR, 2006) for the Anoka Sand Plain Subsection, and the oak savannas and dunes remaining in this subsection are some of the highest quality examples of these habitat types remaining in the state.

Surveys of rare animals in this subsection were completed by the Minnesota County Biological Survey (MCBS) in 1990. Due to the high number of counties surveyed during that field season, many portions of this subsection were not surveyed. Additionally, these surveys did not include invertebrate species.

To address these issues, as well as others, a State Wildlife Grant project T-13-R-1, entitled "Rare Wildlife and Habitat Surveys in Oak Savannas of the Anoka Sand Plain Subsection" (hereafter ASP1) was undertaken in 2008 and 2009 (Harper et al., 2010). While ASP1 was highly successful in identifying the persistence of many SGCN on this landscape, it also brought to light gaps in understanding of SGCN and their habitats.

One of these knowledge gaps we chose to address was the lack of information on the western hog-nosed snake (*Heterodon nasicus*). Little is understood about the habitat use characteristics of this SGCN throughout much of its range, making informed management decisions targeting this species in Minnesota difficult (Edgren, 1955; Wright and Didiuk, 1998; Eckerman unpublished). Several other SGCN were also identified in ASP1 as requiring more study (Table 1).

Many of the trends anecdotally observed during ASP1 appear to be wholly unstudied in the Anoka Sand Plain and may greatly influence the management strategies used on this landscape. For example, during ASP1 it was anecdotally observed that certain patches of habitat on the landscape contain large concentrations of rare biota of diverse taxa. Some of the questions raised included the following. Why do large numbers of rare species congregate in discrete patches of habitat? Why are other, nearby patches more sparsely inhabited or uninhabited? No previous studies were found that address these issues. Several habitat characteristics were observed across these "hot spots" such as exposed sandy soil, but these have not been sufficiently studied to draw conclusions about what makes a certain location a "hot spot."

The goal of this project is to better understand the habitat use characteristics of the SGCN that occur in this diminishing landscape. This project thus addresses Goal II of SWAP (improve knowledge about SGCN) (MN DNR, 2006) by implementing Strategy IIA, surveying SGCN populations and habitats.

This project also addresses Goal I of SWAP (stabilize and increase SGCN populations) by identifying habitats within the Anoka Sand Plain that support, and may be critical to, SGCN, and using this information to provide technical assistance to individuals and/or agencies responsible for the management of key habitats.

To address these goals we pioneered the use of harmonic radar tracking technology to narrow the knowledge gap on the daily habits and habitat preferences of western hog-nosed snakes. The data collected via harmonic radar telemetry has then been compared to data obtained via traditional radio telemetry techniques in order to assess effectiveness of harmonic radar tracking technology. We concurrently conducted detailed rare species and habitat parameter surveys to inform habitat use and selection by several taxonomic groups of rare species on the Anoka Sand Plain.

This report includes information on all species found (Tables 2a-d), all SGCN found, habitat trends observed and results of the western hog-nosed snake tracking study. All new or updated occurrences of species tracked in the Natural Heritage Information System (NHIS) will be submitted for inclusion in that database.

Objectives:

Work completed in 2010 and 2011 met the following objectives:

1. Conduct occurrence surveys within Sherburne National Wildlife Refuge and Sand Dunes State Forest, Sherburne County, focusing on target SGCN identified in ASP1 as requiring more study (Table 1)
2. Identify the key microhabitat components selected by target SGCN within survey sites (Figure 2 for map of survey sites).

Methods – Pre-field Season

1) Survey area selection

Study sites were selected from the group of nine managed areas that were initially surveyed during ASP1. In order to maintain the feasibility of conducting more detailed rare animal occurrence, habitat, and animal tracking surveys, we focused on Sherburne National Wildlife Refuge, Sand Dunes State Forest and Uncas Dunes Scientific and Natural Area (which is largely contained within the state forest). These three managed areas occur in close proximity (Figure 1) and were found to have the highest abundance and diversity of rare species among the habitats targeted during the ASP1 project.

Twelve study sites were selected within the three managed areas chosen for this study; each study site measured 2500 m^2 (Figure 2) and was selected based on the occurrence of rare species and habitat observations made during the 2008 and 2009 field seasons of ASP1, review of aerial photographs, and ground reconnaissance. These 12 sites allowed surveys to focus high intensity efforts in pre-defined locations for detailed habitat characterization work; plant community vegetation plots (relevès); and invertebrate, bird, mammal and herpetofaunal surveys. Western hog-nosed snakes were tracked beyond the bounds of study sites.

2) Harmonic radar tracking system research and tag development

One goal of this study was to evaluate the use of a new form of telemetry technology called harmonic radar (HR) in tracking western hog-nosed snakes. Only a few studies using HR to track vertebrates have been published (Webb and Shine, 1997, 1998; Gourret et al., 2011). Because HR tags for use in biological research are not currently commercially available, we adapted the methods used in other studies, and used additional resources provided by the manufacturer of the hand-held receiver (RECCO, AB) to design, build and test tags for use during this project. We also consulted a veterinarian to ensure the tracking tags were built such that they were implantable subcutaneously. Surgical procedures specific to HR tags were developed in cooperation with the veterinarian and will be published in a peer-reviewed journal.

Once the best performing HR tag was developed, preliminary testing and practice using the RECCO receiver and home-made tags was performed by field staff to reduce user-error in the field. There are several limitations to HR technology, including signal-range and multiple tag signal differentiation. To address the latter limitation, we also implanted high-powered (Trovan, Ltd.) passive integrated transponder (PIT) tags to uniquely identify individuals buried in the soil (Figure 3a). We achieved a maximum PIT tag read distance of 25-30 cm for above-ground individuals and 15-25 cm for below-ground individuals (through sandy soil).

During the 2010 field season HR tracking technology was the only means of remote detection utilized (Figure 3b). However, after one season of experimentation with this technology we decided to incorporate traditional radio tracking (VHF) techniques (during the 2011 field season). The benefit of adding VHF tags was twofold. First it allowed for a side-by-side comparison of home range data collected using each method. Second it allowed us to determine whether non-detections using HR were a result of individuals moving far outside the designated search areas or if they were seeking refuge deep under-ground and thus undetectable given signal-range limitations.

Methods – Field Survey and Data Collection

3) Site Habitat Characterization
Staff: Erica Hoaglund, Adam Doll, volunteers

Detailed habitat classification data were collected at each of the 12 study sites (Figure 3c). Each site was initially designated with a center point, and then a 2500 m^2 plot was delineated around the point using flags. Finally, the plots were divided into 25 subplots measuring 100 m^2 for microhabitat scale data collection.

At each site several “levels” of data were collected. First “macro”, or plot level, data were collected within the delineated 2500 m^2 plots. These data included: maximum slope of plot, lowest and highest elevation points, distance from center of plot to each nearest adjacent habitat type (see below), presence of roads and trails, and species of overstory trees present. Micro-level data collected within each 100 m^2 sub-plot included percent cover estimates of the following variables: woody vegetation (low and tall), graminoid plants (low and tall), herbaceous plants (low and tall), standing water, litter cover, bare earth, and mosses/lichens. For variables with a “low” or “high” categorical variable, low was defined as < waist height and high was defined at > waist height (or approximately 1 m). Also collected within each sub-plot were: the height of the vegetation at the center of the sub-plot, the depth of any litter present at the center of the sub-plot, major soil type, number of overstory trees, number of gopher mounds, numbers of holes and burrows, and numbers of large rocks (≥ 5cm), woody objects and non-woody objects (such as large pieces of trash or metal).

Macro habitat type of each site was qualitatively chosen by observers from a pre-set list of types (grassland, old field, native prairie, grazed pasture, agricultural field, oak savanna, deciduous forest, pine plantation, road, and ditch). Grassland type was used when a habitat consisted mostly of graminoid cover of one or a few types and prairie was used when a site exhibited a more diverse array of grasses and forbs and open sand but still did not have a major woody or tree component. Old field and grazed pasture were rarely used and then only if the history of the area was readily apparent on the ground. Agricultural field denoted a field currently used for row crop production (e.g., corn, soybean, etc.). Oak savanna was used when a site was more complex than a prairie or grassland, with more woody and tree components, but still not densely enclosed. Deciduous forest was used to describe oak woodland or other upland non-pine forest. Planted pine was used to describe the areas currently used for primarily white pine timber production, where pines are essentially a mono-crop. Road was used for any road passable and commonly used by motor vehicles and ditch was used to describe the disturbed areas adjacent to roads. Each macro habitat type was assigned based on general impression of the site by non-vegetation survey staff and does not necessarily reflect the native plant community determined during relevé surveys.

4) Study Site Surveys

Targeted SGCN surveys using taxon- and species-specific methods were conducted April-October 2010 and 2011 using a variety of taxon-specific methods that were developed during ASP1 or adapted from published literature (Corn and Bury, 1990; Heyer et al., 1994; Wilson et al., 1996) (Table 1). The more detailed telemetry study of the western hog-nosed snakes continued throughout the winter of 2010 and 2011 as long as tag signals were detectable. Western hog-nosed snakes were tracked during the entire project period using either harmonic radar (HR) or VHF radio telemetry. Detailed habitat data were collected at each observation location (see below). A relevè to assess plant community structure, species composition, and quality was conducted at each of the 12 survey sites. Targeted plant surveys of species or groups important to the target invertebrates of this study were conducted.

Detailed survey methods for the various SGCN and plants will follow below.

Mammal Occurrence Surveys:

Staff: Erica Hoaglund, Christopher E. Smith, Adam Doll

Small mammals were surveyed using Sherman style live trap grid arrays. Study sites were trapped if they lacked a post 2008 observation of the target small mammal species, the plains pocket mouse (*Perognathus flavescens*). Sites trapped in 2010 that did not yield pocket mice observations were re-trapped in 2011. Trap grids consisted of four rows of 10 traps each; traps were spaced approximately 15 meters from other traps in adjacent rows and columns. All traps were baited with peanut butter and oats. Traps were opened in the evening, checked and closed each morning, and left closed during the heat of the day. Trap grids were run at each site for three consecutive nights. Standard data were recorded for all species of animals captured (e.g., species, gender, reproductive status, weight), and each animal was given a temporary mark, and released. Photographic vouchers were taken of any plains pocket mice captured.

It is important to note that while all of the target species of this project merit detailed study, time and resource constraints limited the scope to current presence/absence for target small mammal species (the plains pocket mouse) at each survey site. This methodology used unequal trapping effort at each sampling site (i.e. sites without plains pocket mice observations received more trapping effort than those with verified current records).

Bird Point Counts:

Surveyor: Paul Spreitzer

Point counts were conducted at the center waypoint of each of the twelve study sites in June 2010 and between May and June 2011. Each site was surveyed three times each year, for a total of six point counts per site during the study.

Point counts were conducted from 15 min before sunrise to approximately four hours after sunrise. Point counts ended slightly earlier or later depending on bird activity and weather conditions. Point counts were not conducted during heavy rain, high winds, dense fog or other weather that negatively affects bird activity.

Datasheets were completed for every point count, whether birds were observed or not. All birds heard or observed during a 10-minute survey period were recorded. Survey periods were split into two five-minute intervals (Fuller and Langslow, 1984). For each species, the number of singing males heard was recorded separately for birds located within a 50 m radius of the observer, and for those beyond 50 m. Observations of female, juvenile and unknown birds were also recorded. Contractors were instructed not to count the same individual more than once (e.g., the same pair of sandhill cranes may be audible at two consecutive points). Contractors recorded flyovers separately, and noted bird behavior within the habitat (e.g., foraging, nesting, etc.). Target, Biotics' tracked, or SGCN birds were also recorded incidentally when observed during other survey activities by field staff.

Reptile Surveys:
Staff: Erica Hoaglund, Christopher E. Smith

Targeted reptile species searches: Throughout both field seasons western hog-nosed snakes were targeted during searches in or near each study site. These activities were focused in May and June when the snakes are most active. Targeted searches consisted of timed visual encounter searches on each of the 12 sites and the surrounding areas. Searches were completed by walking target areas in tight transects and scanning the ground carefully. During May and June any healthy western hog-nosed snake encountered that was ≥ 15 grams was collected for implantation (see: "western hog-nosed snake remote tracking study" below). Any western hog-nosed snake encountered after June was not implanted with a tracking tag, but was implanted with a PIT tag to facilitate future identification. The following microhabitat data were collected within 1 m^2 of each occurrence point for western hog-nosed snakes (for both tracked and incidental observations): air temperature, below soil (15cm) temperature and soil surface temperature, size of nearby rocks and logs, and number of burrow holes and gopher mounds present. Percent cover of the following variables were also recorded within 1 m^2 of the snake: rock, dead vegetation, open sand, woody debris, tall and low graminoids, tall and short forbs, tall and short woody vegetation and moss. Soil type and canopy cover at snake locations were also recorded. In addition, several macro habitat variables were estimate at the point of encounter: distance to nearest open water, distance to nearest over-story tree, distance to nearest trail, and distance to nearest road.

Gophersnakes observed during targeted visual encounter searches that weighed ≥ 50 grams were PIT tagged, photographed and immediately released. PIT tags were injected subcutaneously along the left side of the posterior 1/3 of the body between dorsal scale rows four to six. If a Gophersnake was eligible to be PIT tagged, we also recorded gender (determined by probing), weight, total-body-length (TBL) and snout-vent-length (SVL) measurements.

During targeted reptile searches any other reptile or amphibian species of interest, or presenting unique natural history observations, were also recorded.

Western hog-nosed snake remote tracking study: Western hog-nosed snakes were surgically implanted with harmonic radar (HR) or radio telemetry (VHF) tracking tags and followed throughout the project period to better understand their natural history and microhabitat use. Western hog-nosed snakes were targeted using terrestrial visual encounter search techniques (described above) during the spring of each field season.

Once located, snakes were captured and evaluated for their suitability to receive a tracking tag. Although both types of tag (HR and VHF) are very small, so are juvenile and hatchling Western hog-nosed snakes and thus a minimum weight for a snake at time of surgery was set in order to ensure animal safety; a minimum weight of > 15 grams at time of capture was observed. Captured snakes were collected in a pillowcase, tagged with date, study site, weight and gender. Snakes were then taken to a vet for surgical implantation within 24-48 hours of capture. All snakes were anesthetized and HR or VHF tags were implanted subcutaneously. A few stitches and glue were used to close the incision. Each snake was then injected with a high powered PIT tag (Trovan, Ltd.) to facilitate unique identification (Figure 3b). Although VHF tags do have the capacity for unique identification of an individual without the aid of a PIT tag, this ability ends when the battery in the tag dies, thus a PIT tag was added to facilitate unique identification after the expected life of the tracking transmitter. Snakes were held in 10-gallon aquaria with secure lids and partial heat for between 12 to 36 hours post-surgery. They were then released at the site of capture. No snake located after June received an implanted tag, due to risk of poor recovery.

Once released, an attempt was made to relocate each snake at least twice a week using an Advanced Telemetry Systems (ATS), Inc. 164 – 164.99 MHz frequencies (VHF) receiver, and handheld antenna. Once a western hog-nosed snake was relocated, microhabitat data described above were recorded within 1 m^2 of the animal's location. If a snake was relocated using HR tracking, an attempt was made to read the animal's PIT tag to identify individual snakes (VHF tags each have a unique frequency and thus a PIT tag read was not *necessary* for confident individual recognition). If the snake was found above the surface basking (not moving), an attempt was made to read its PIT tag and collect data for its location without disturbing the animal. If the snake was found "on-the-move" it was briefly captured to collect PIT tag number, weight and verify health, and then quickly released. If a snake was found in an apparently identical subterranean location for more than three consecutive visits attempts were made to verify life by inducing movement, or by careful excavation of the animal (a technique very rarely used).

Invertebrate Surveys:
Staff: Erica Hoaglund, Christopher E. Smith, Adam Doll

Invertebrate surveys were conducted using various accepted methods designed to target each species of interest in this study (Table 1). Literature and personal communications suggested that night-time light sheeting was an appropriate technique to survey the little white tiger beetle (*Cicindela lepida*); therefore at least one nighttime light sheet survey was conducted at each survey site. The light sheet set up consisted of a white bed sheet suspended vertically on a frame with a UV spectrum light suspended from above in the approximate center of the sheet. The sheet and light set-up were placed in an area of abundant open sand whenever possible within each survey site. Sites with abundant open sand are the areas where target invertebrates were most often encountered during ASP I (Harper et al., 2009) and thus deemed the most suitable locations for trapping. Abundant open sand also facilitated easy observation of invertebrates as they approached the light sheet. The sheet was set up and light turned on at dusk and was monitored for insect arrivals for at least one hour or until temperatures fell below 65 degrees Fahrenheit.

Little white tiger beetles (*Cicindela lepida*) and northern barrens tiger beetles (*Cicindela patruela patruela*) were also targeted using daytime visual encounter surveys with and without binoculars. Visual encounter surveys consisted of timed searches in areas of suitable habitat within each site during conditions suitable for peak tiger beetle activity (warm sunny days). The Leonard's skipper (*Hesperia leonardus*) and the Uncas skipper (*Hesperia uncas*) were also targeted using visual encounter surveys, primarily in areas where known host plants were present or nectaring plants were in bloom.

The two target jumping spider species *Metaphidippus arizonensis* (no common name) and *Tutelina formicaria* (no common name) were targeted with net sweeps in suitable habitat at least once at each site and visual encounter surveys repeatedly throughout the summer at each study site. Net sweeps consisted of 10-20 sweeps through suitable habitat in July or August. Visual encounter surveys focused on silken retreat observation in retained seed heads of *Penstemon spp.* and roundhead bush clover (*Lespedeza capitata*). Once silken retreats were identified, a careful visual inspection was done to determine the species of spider guarding it. All targeted animals found were photo-documented and released.

Targeted Plant and Relevé Surveys:
Staff: Hannah Texler, and Marcel R. Jouseau

During the 2010 field season, targeted surveys of four important plant species were completed across all twelve study sites. The target plants surveyed were: hairy grama (*Bouteloua hirsuta*), roundheaded bush clover (*Lespedeza capitata*), blazing star species (*Liatris spp.*), and large flowered penstemon (*Penstemon grandiflorus*). These plants were targeted because of their importance to the rare invertebrate species of the area, including the invertebrates targeted for this study. Hairy grama is the only known host plant for the larval stage of the Uncas skipper (MN DNR, 2008). Roundheaded bush clover and large flowered penstemon are associated with both target spider species *(M. arizonensis and T. formicaria*); both jumping spider species create nests in the retained seed heads of these plant species (MN DNR, 2008). Blazing star species, along with other plant species with showy flowers, are avidly sought by the Leonard's skipper for nectar (MN DNR, 2008).

The targeted surveys for these plants focused on presence/absence of each species at each site as well as some measure of abundance. In order to accomplish this, the surveyor traveled through each site on foot in rough transects in order to observe the largest possible amount of suitable habitat in and near the site. When a target plant was found, its location was recorded using a GPS unit and notes were made as to the species' identity. Estimation of abundance was done in two ways (as described by the surveyor Marcel R. Jouseau): 1) If plants could be circumscribed in a circle of an approximate radius of 10 feet, the number of plants in that circle was recorded, 2) If the cluster was much larger or of irregular shape, the surveyor walked around this artificial polygon recording a few locations in the GPS and the number of plants within that artificial polygon. Where the density of the plant species was substantial and over a large area, the estimated number of plants per m^2 was recorded for each recorded waypoint.

Relevès measuring 400 m^2 were also completed at the center point of every study site following the field protocols established in A Handbook for Collecting Vegetation Plot Data in Minnesota: The Relevé Method (MN DNR, 2007).

Methods – Data Analysis and Report Writing

Western hog-nosed snake tracking study data analysis
Staff: Erica Hoaglund, Christopher E. Smith

Radio (VHF) and harmonic radar telemetry (HR) data were used to examine movement patterns in western hog-nosed snakes in 2010 and 2011. Active-season home range estimates (the area of a study site and surrounding areas that was used by an individual during the active season) were generated using 95% kernel densities (KD) and 100% minimum convex polygons (MCP). In addition, we generated 50% KD to better elucidate activity centers for each individual. All home range estimates were generated using the Geospatial Modeling Environment software (GME, v0.6.1) in conjunction with R (v2.14), StatConn DCOM (v3.2) and ArcGIS (v10.0).

The kernel density estimator is a nonparametric estimator of an individual's home range constructed using a modeled "probability of use" given known locations (Worton, 1989). We used least squares cross-validation to select the smoothing parameter for all KD estimates to allow easy comparison to prior work (Seaman and Powell, 1996; Marshall et al., 2006; Durbian et al., 2008). The MCP method of home range estimation generates an "area of use" for an individual by enclosing all observations within a single polygon with no concavities within that form (Jennrich and Turner, 1969). For all analyses we subdivided telemetry data by method (VHF vs. HR). Individuals that were tracked using VHF radio telemetry for ≥ 60 days were included in analyses; while individuals tracked using HR had to have ≥ 3 observations spanning ≥ 14 days. Statistical differences between home range size estimates were evaluated using Welch's T-test that allowed for unequal variance.

Habitat variables collected at each[a] tracked hog-nosed snake observation location were analyzed by percent habitat use for each snake, and then averaged across all individuals, n = 24.

[a]Note: One harmonic radar tracked individual was removed from observation average calculations because after initial implantation the snake was never observed again.

Data Management and Report Writing:
Staff: Erica Hoaglund, Christopher E. Smith

All data obtained during the project period were entered into Excel spread-sheets. All photos taken during field surveys will be catalogued and entered into a photo tracking spread-sheet. In addition, observations (typically dead-on-road specimens, audio recordings, or photographic vouchers) that represented new or updated county records were accessioned into the James Ford Bell Museum of Natural History (JFBM) at the University of Minnesota, St. Paul, MN. All occurrences of MN DNR tracked species (species tracked in NatureServe) were submitted to the Biotics database for entry.

Data collected during this project will also be entered into the MN DNR Observation Database where it will be accessible for use by others. Data obtained during this study that represented newly documented or rarely observed behavior, natural history, and/or geographical distribution information are being prepared for submission to peer-reviewed journals.

Results - Survey Findings

The first objective of this project was to conduct intense targeted surveys at locations where SGCN had been identified during a previous survey project (ASP I). Nine of the 15 targeted species were documented during this study (Table 1). In total, 27 SGCN were documented (including nine targeted species) along with 70 non-SGCN (Tables 2a-d).

The second objective of this project focused on increasing our understanding of the habitat needs for many of the rare SGCN in this area. This was done by examining in detail the locations where western hog-nosed snakes were located and the habitat present at the 12 survey sites.

Survey Site Descriptions (see Figure 2 for map of site locations):

Note: These site descriptions list a tier ranking given to the site after field surveys were complete and were based most heavily on the number of targeted species found. Numbers of SGCN were also taken into consideration, especially if sites ranked near the cut-off for a given tier. Tier I indicates that the site had a high number of target (≥ 4) and SGCN species (≥ 11) documented within it, down to tier III sites which had the fewest number of target (≤ 3) and SGCN species (≤ 8) documented compared to all other study sites in this survey. See "Comparison of Study Sites" on page 22 for full description of tier rankings.

Site-1: [redacted]

Site-1 is located directly east of [redacted] The study site was located within a prairie opening of approximately 50,000 m^2 and was bordered by a county highway to the north and oak woodland to the west, south and east. The area is dominated by dry barrens prairie and early succession oak savanna with sandy soils. The nearest wetland was approximately 170 m southwest of the centroid site point. The area is bisected by two public walking trails that receive heavy use during the spring, summer and fall. Plains pocket gopher (*Geomys bursarius)* mounds were prevalent. Tier I.

Site-2: [redacted]

Site-2 is located directly [redacted] The study site was located within an opening north of County Highway [redacted] walking path. This area was approximately 44,000 m^2 of dry barrens prairie bordered by oak woodland to the north and west that is being actively restored to oak savanna. The southern edge is bordered by a county highway, with additional dry barrens prairie bordering the eastern edge. The nearest wetland was approximately 180 m southwest of the centroid site point. The eastern edge of the study site is bordered by a public walking trail that receives heavy use during spring, summer and fall. Plains pocket gopher (*Geomys bursarius)* mounds were prevalent. Tier I

Site-3: [redacted]

Site-3 is located approximately [redacted] This area was approximately 200,000 m^2 of dry barrens prairie bordered by wetlands to the south and west, oak woodland to the north, and [redacted] road and additional dry barrens prairie to the east. The nearest wetland was approximately 140 m southwest of the centroid site point. Plains pocket gopher (*Geomys bursarius)* mounds were prevalent. Tier II.

Site-4: [redacted]

Site-4 is located approximately [redacted] This area was approximately 60,000 m^2 of dry barrens prairie bisected by walking trails and a shallow wetland. The area was bordered by [redacted] and wetlands to the north and east. The nearest wetland was approximately 50 m south of the centroid site point. Plains pocket gopher (*Geomys bursarius)* mounds were prevalent. Tier I.

Site-5: [redacted]

Site-5 is located approximately [redacted] [redacted] The area was approximately 100,000 m^2 of oak savanna bisected by [redacted] burn break. The area was bordered by wetlands to the north and west, and oak woodland and dry barrens prairie in the process of being restored to oak savanna to the south and east. The nearest wetland was approximately 40 m southwest of the centroid site point. Plains pocket gopher (*Geomys bursarius)* mounds were prevalent. Tier II.

Site-6: “N/A”

Site-6 is located within a small patch of prairie surrounded by [redacted] The area was approximately 2,750 m^2 of dry barrens prairie interspersed with small pines (*Pinus* spp.). The small patch is bordered by [redacted] [redacted]. The nearest wetland was approximately 225 m south of the centroid site point. Plains pocket gopher (*Geomys bursarius)* mounds were prevalent. Tier III.

Site-7: "N/A"

Site-7 is located within a small patch of dry barrens prairie surround by [redacted]. The area was approximately 2,250 m^2 of prairie interspersed with small pines (*Pinus* spp.). The small patch is bordered by [redacted] to the south. The nearest wetland was approximately 250 m east of the centroid site point. Plains pocket gopher (*Geomys bursarius)* mounds were prevalent. Tier II.

Site-8: "N/A"

Site-8 is located within a small patch of dry barrens prairie surround by [redacted] The area was approximately 7,000 m^2 of prairie interspersed with small pines (*Pinus* spp.). The small patch is bordered by [redacted] to the east. The nearest wetland was approximately 200 m northwest of the centroid site point. Plains pocket gopher (*Geomys bursarius)* mounds were prevalent. Tier III.

Site-9: "N/A"

Site-9 is located within a dry barrens prairie surround by oak woodland within [redacted] This area was approximately 32,000 m^2 of dry barrens prairie bordered by oak woodland to the south and west that is being actively restored to oak savanna. The site is bordered by wetlands to the north and additional prairie to the east. The nearest wetland was approximately 80 m northwest of the centroid site point. Plains pocket gopher (*Geomys bursarius)* mounds were present but relatively less common compared to other sites. Tier I.

Site-10: "N/A"

Site-10 is located within a grassland / prairie surround by oak woodland within [redacted] This area was approximately 45,000 m^2 of dry barrens prairie with areas of mesic grassland bordered by oak woodland to the north, south and west. County Road [redacted] The nearest wetland was approximately 173 m west of the centroid site point. Plains pocket gopher (*Geomys bursarius)* mounds were present but relatively less common compared to other sites. Tier III.

Site-11: "N/A"

Site-11 is located within a small patch of dry barrens prairie surround by [redacted] The area was approximately 13,000 m^2 of prairie interspersed with small pines (*Pinus* spp.). The site is bisected by [redacted] The nearest wetland was approximately 100 m northwest of the centroid site point. Plains pocket gopher (*Geomys bursarius)* mounds were prevalent. Tier II.

Site-12: "N/A"

Site-12 is located within a small patch of dry barrens prairie surround by [redacted] The area was approximately 10,000 m^2 of prairie interspersed with small pines (*Pinus* spp.). The site is bisected by [redacted] actively being restored to oak savanna. The nearest wetland was approximately 95 m south of the centroid site point. Plains pocket gopher (*Geomys bursarius)* mounds were prevalent. Tier III.

Mammal Occurrence Survey Results:

Small mammal trapping targeted the plains pocket mouse (*Perognathus flavescens*) at eight of the 12 designated survey areas during both 2010 and 2011. The plains pocket mouse was documented at four of the eight survey areas (Sites -4, -6, -9 and -11). Four sites at which this species had been observed in 2009 - 2010 were not re-trapped during this study (Sites-1, -2, -5, and -7). The remaining four sites that lacked plains pocket mouse records as of fall 2011 were Sites-3 and -10 (Sherburne NWR), Site -8 (Sand Dunes SF) and Site-12 (Uncas Dunes SNA).

All small mammals captured while targeting plains pocket mice were documented. White-footed mice (*Peromyscus leucopus*), prairie deer mice (*Peromyscus maniculatus bairdii*), northern short-tailed shrews (*Blarina brevicauda*), masked shrews (*Sorex cinereus*), meadow voles (*Microtus pennsylvanicus*), and thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*) were documented in study sites in 2010 or 2011 (see tables 3 – 14). The small mammal surveys (2010 and 2011) resulted in 148 (124 in 2010 and 24 in 2011) individual captures during 1380 trap nights (1080 trap-nights in 2010 and 300 trap-nights in 2011). Forty of the captures represent re-captured individuals for the same sample period. Plains pocket mice comprised 0.10% (n=12) of the 2010 captures and 0.08% (n=2) of the 2011 captures.

Bird Point Count Results:

Over the course of this project 72 bird point counts (three per site in 2010 and three per site in 2011) were conducted at all 12 study sites. These surveys yielded 982 visual or aural avian observations (see Table 2b for all bird species documented). Point count surveys documented two of the seven targeted bird species: Grasshopper Sparrows at Sites-1, -2, -3, -4, -9, and -10 and Eastern Meadowlarks at Sites-1 and -3 (Tables 3 – 14). In addition, Common Nighthawks were documented at (or near) Site-1, and Whip-poor-wills at (or near) Sites-1, -6, -7, -8, -9, -11, -12 by non-point count targeted surveys. Red-headed woodpeckers were observed twice, but neither observation was at a study site. Bobolink and Loggerhead Shrike were not observed at any study site. Site-5 was the only study site at which no target bird species were documented.

Targeted Western Hog-nosed Snake Search Results:

Western hog-nosed snakes were the only herpetofaunal (herp) SGCN targeted during this project and they were documented at seven of the 12 study sites (Tables 3-14). Incidental herp SGCN observations were also recorded. Nine total herp species were documented within study sites between 2010 and 2011; including Gophersnakes (*Pituophis catenifer*) and Blanding's turtles (*Emydoidea blandingii*) which are both SGCN (Table 2c).

In 2010, 11,256 person minutes (187.6 hours) were spent conducting visual encounter surveys (VES) within all 12 survey sites. These surveys targeted western hog-nosed snakes large enough to implant with a tracking tag. Thirteen snakes were implanted with HR tags. Six additional snakes were found but were not implanted with tracking tags. In 2011, 1,989 VES person minutes (33.15 hours) were spent locating additional study subjects. Fifteen snakes were implanted with VHF (n=14) or HR (n=1) tags. Nineteen additional snakes were found but were not implanted with tracking tags. Much of this search effort occurred during May and June in order to obtain study subjects to implant with tracking devices. The remainder of the field season focused on tracking individuals found during the spring searches. The difference in VES minutes from 2010 to 2011 is attributed to the fact that in the spring of 2011, snakes already implanted with tracking tags served to quickly lead us to new individuals early in the year and thus we were more quickly able to deploy all available tracking tags that year with less search effort.

Fifty-three individual western hog-nosed snakes were PIT tagged at seven of the 12 study sites. In 2010, 19 western hog-nosed snakes were PIT tagged at Sites-1, -2, -3, -4, -5, and -11, with 13 of those found implanted with harmonic radar tracking tags (the remaining 6 were either found too late or deemed too small or unhealthy to undergo surgery). At least one snake from every site where western hog-nosed snakes were found in 2010 was implanted with a harmonic radar tracking tag. In 2011, 34 western hog-nosed snakes were PIT tagged at Sites-1, -2, -3, -4, -6, and -11. Fourteen of those PIT tagged were implanted with VHF transmitters and one additional snake was implanted with a harmonic radar tracking tag.

Although Gophersnakes were not targeted during this study, when individuals were encountered they were also PIT tagged to facilitate individual recognition and to provide data for future population monitoring efforts. During the course of this project 86 Gophersnakes were PIT tagged in the study area consisting of Sherburne NWR, Sand Dunes SF and Uncas Dunes SNA.

Western Hog-nosed Snake Remote Tracking Study Results:

During this project 505.6 person hours were spent tracking hog-nosed snakes. This effort was distributed between two types of tracking technology: 301.6 hours of time spent tracking with harmonic radar, and 204 hours of time spent tracking with VHF. Between 2010 and 2011, 28 western hog-nosed snakes were implanted with either harmonic radar tracking tags, or VHF radio transmitters (sample size of 14 for both tag types). All sites with tracked western hog-nosed snakes except one had at least one adult male and one adult female implanted with a tracking tag of some type at that site, the exception being Site-3 where only female snakes were implanted.

Overall 16 of the 28 snakes (10 snakes tracked using VHF radio telemetry and six using harmonic radar) implanted with tags had sufficient data (see methods section for exclusion criteria) to be included in home range size estimates (see Appendix I for individual home range estimates and maps).Of these, eight were female and eight were male, all males were considered adults and all females except one were considered adults. The smallest snake that received an implanted tag weighed 19 grams (a female) and the heaviest weighed 240 grams (also female). This group included five snakes found in Sand Dunes SF ([redacted]), and 11 in Sherburne NWR. Individuals were located between 3 and 53 times from May of 2010 to November of 2011.

The two tracking technologies were compared using mean minimum convex polygon (MCP) and 95% kernel density (KD) home range estimates as well as 50% KD activity center size estimates. The mean home range size estimated for harmonic radar tracked snakes using MCP was 1.17 hectares (ha), and the mean home range size estimate for VHF tracked snakes using MCP was 11.22 ha. We used Welch's T-test, to account for unequal variance using $\alpha = 0.05$, and found that mean home range estimates were significantly smaller for HR tracked snakes ($t = 3.4$, $df = 9$, $p < 0.01$). The same group of HR and VHF tracked snakes' mean home range sizes were then estimated using the 95% KD method at a mean of 3.64 ha and 26.08 ha, respectively. This again showed significantly smaller mean home range size estimates for HR tracked snakes ($t = 3.4$, $df = 9$, $p < 0.01$). The third habitat use analysis run was a 50% KD, or "activity center" estimation. Harmonic radar tracked snakes were estimated to have significantly smaller mean activity centers at 0.93 ha when compared to VHF tracked snakes that had mean activity centers of 5.90 ha ($t = 3.2$, $df = 9$, $p < 0.05$).

We then compared MCP and 95% KD estimates using a paired T-test to determine if the observed difference between the two estimation techniques was statistically significant. The difference between home range estimates calculated using MCP and 95% KD methodology for the snakes tracked with VHF and HR technologies was found to be statistically significant ($t = 3.7$, $df = 9$, $p < 0.01$ and $t = 3.2$, $df = 5$, $p < 0.05$, respectively).

Habitat Use Findings:

Throughout this two year study, 589 habitat location data points were collected; 415 of these locations were within Sherburne NWR and 174 were in Sand Dunes State Forest.

Tracked snakes were observed an in the following macro habitat types in descending frequency (percent of observations occurring in the listed habitat type following each type): Grassland (31.30%), Ditch (27.04%), Oak Savanna (21.55%), Native Prairie (10.37%), Old Field (4.36%), Edge (2.61%) Planted Pines (1.34%), Emergent Marsh (0.55%), Shrub Swamp (0.49%), Deciduous Forest (0.27%), and Wet Meadow (0.25%). The average one square meter of micro-habitat surrounding a tracked individual snake's location was characterized by the following cover-types in descending amount (with the average percent of cover following each cover-type): Low graminoids (31.13%), Open sand (29.22%), Dead vegetation (19.68%), Low herbs (7.53%), Moss (4.57%), Low woody vegetation (2.88%), Tall graminoids (2.85%), Tall woody vegetation (0.67%), Woody debris (0.39%), and Rock (0.13%). There was also an average canopy cover of 1.93% over snake locations (however it is interesting to note that this value did occasionally range up to 100% canopy cover).

Tracked snakes were observed the following distances from open water in descending frequency (percent of observations occurring at that distance following each distance category): Greater than 100m from open water (88.59%), between 20 and 100 meters from open water (9.25%), between five and 20 meters from open water (3.14%), between one and five meters from open water (0.28%), and less than one meter from open water (0.24%).

Tracked snakes were observed the following distances from an overstory tree in descending order (percent of observations occurring at that distance following each distance category): Greater than 100 meters from an overstory tree (40.86%), between 20 and 100 meters from an overstory tree (27.03%), between five and 20 meters from an overstory tree (17.55%), between one and five meters from an overstory tree (9.84%), and less than one meter from an overstory tree (4.7%).

Tracked snakes were observed the following distances from a paved road in descending order (percent of observations occurring at that distance following each distance category): Greater than 100 meters from an paved road (51.90%), between 20 and 100 meters from a paved road (21.47%), between five and 20 meters from a paved road (12.12%), between one and five meters from a paved road (11.71%), and less than one meter from a paved road (2.73%).

Tracked snakes were found near zero large rocks 84.75% of the time. The remaining 14.78% of the time any nearby rocks were under 5 cm and thus not counted as a “large rock” habitat feature.

Tracked snakes were found near zero large logs 91.17% of the time. They were found within one square meter of logs measuring between 11 and 20 cm in diameter 4.08% of the time, near logs more than 21 cm in diameter 3.32% of the time, near logs with diameters between one and five centimeters 3.03% of the time, and near logs between 6 and 10 cm in diameter 0.90% of the time.

Tracked snakes were observed near the following numbers of burrow holes in descending order (with percent of observations occurring near that number of holes following each hole count): Zero holes (38.78%), one hole (33.76%), two holes (17.02%) four or more holes (5.62%), and three holes (4.64%). A maximum of eight holes within one square meter of a snake was recorded.

Tracked snakes were observed near the following numbers of gopher mounds in descending order (with percent of observations occurring near that number of gopher mounds following each hole count): Zero gopher mounds (41.82%), two gopher mounds (23.85%), one gopher mound (19.61%), three gopher mounds (6.77%) and four or more gopher mounds (6.35%).

Tracked snakes were found 95.54% of the time on sandy soil, and 3.54% of the time on soil comprised of decomposing vegetation. Much of the time (56.59%) the soil was classified as dry, 25.89% of the time it was classified as moist, and 16.11% of the time is was classified as of moderate moisture. The soil was most often (71.03%) classified as being of loose consistency, 24.25% of the time as being of somewhat compact consistency, and 3.80% of the time as being of compact consistency.

Invertebrate Survey Results:

Three of the six target invertebrate species identified for this project were documented between 2010 and 2011 (Table 1). Across both 2010 and 2011, 30.5 hours were spent searching for the target invertebrate species.

The Leonard's Skipper (*Hesperia leonardus*) was documented at four of the 12 study sites (Sites-4, -5, and -9 in Sherburne NWR and Site-8 in Sand Dunes SF) (Tables 3-14). There was also one report of an individual observed at Site 11 in Sand Dunes SF but it was never verified. Leonard's skippers were always observed in mid- to late-August and in close association with late blooming prairie/grassland flowers (primarily *Liatris* spp.). Although all sites harbored seemingly suitable habitat, Leonard's skippers were not found at eight of the study sites (Tables 3-14). The other target lepidopteron, the Uncas Skipper (*Hesperia uncas*), was not observed on the 12 study sites or by others during targeted searches at historical locations in the vicinity of the 12 study sites. It is likely that the population is extirpated from the area.

Two species of tiger beetles were targeted during 2010 and 2011 using various methods (see methods section). The northern barrens tiger beetle was the only one of the two species documented, and it was only found at a single site; Site-12 in Uncas Dunes SNA (Tables 3-14). Here again, areas of seemingly suitable habitat were searched, but very few records of *C. patruela* were obtained. The other targeted tiger beetle, the little white tiger beetle (*Cicindela lepida*), was not detected.

The third target invertebrate documented was a jumping spider, *Metaphidippus arizonensis* (no common name) (Table 1). This spider was documented at six of the 12 study sites (Site-1, -2, -3, -4, and -9 in Sherburne NWR, and Site-11 in Sand Dunes SF) (Tables 3-14). The second target spider species, *Tutelina formicaria* (no common name) was not documented during this project.

No target invertebrate species were found at Sites-6, -7, or -10 despite searches targeting each species. Also worth noting is that only Site-4 and -9 within Sherburne NWR yielded observations of more than one targeted invertebrate species.

Targeted Plant and Relevé Survey Results:

In 2011, 84 person hours were spent completing 12 relevès, one on each of the selected study sites. Each was a 20 x 20 m vegetation plot, placed at the center point of each study site. Relevès were completed in July of 2011 and each was classified into a native plant community and given a quality ranking of A through D (Table 17 and Appendix II). Eleven of the 12 study sites were classified as the native plant community "Dry Barrens Prairie," however Site-12 did not represent a native plant community and was best described as grassland. Sites-1, -4, and -8 ranked highest out of the 12 study sites with ranks of "B." Sites-3, -5, and -9 all ranked "BC," and Sites -2, -6, -7, -10 and -11 all ranked level "C." Site-12 was below ranking, and was recorded as having no rank.

Also completed during this project were targeted surveys of hairy grama (*Bouteloua hirsuta*), roundheaded bush clover (*Lespedeza capitata*), large flowered penstemon (*Penstemon grandiflorus*), and all blazing star species (*Liatris* spp.) at each study site (Table 16). These plants were targeted because of their importance to the rare invertebrate species targeted in this study (Table 1). Only Site-5 (Table 16) was found to have all four target plant species present. Hairy grama was found at four sites, Roundheaded bush clover was found at nine sites, Blazing star species were found at seven sites and the target penstemon species was found at five sites. Only Sites -6 and -11 completely lacked all target plant species.

It is interesting to note that the designation of "Dry Barrens Prairie" at the 12 study sites of this project contrasts with relevés conducted in native plant communities in 2009 and 2010 during SWG project ASP I, which were placed in Dry Barrens Oak Savanna (canopy cover between 10% and 25%) and Dry-Mesic Oak (Maple) Woodland (canopy cover >25%) native plant communities. Areas with the concentrations of SGCN targeted in this study where more open plant communities than those communities surrounding them.

There was a mean of 23.1 native plant species per 400 m^2 plot in the 12 study sites. The highest native plant species richness (41 species) was Site-1, which had a diverse mix of native prairie species planted by Sherburne National Wildlife Refuge. The next highest was considerably less species-rich (28 species). Mean species richness in Sherburne National Wildlife Refuge relevés was 26.4 species, compared to 18.4 species in Sand Dunes State Forest relevés. Overall quality ranks ranged from B to C, with no quality rank assigned to the old field in Site-12. When numerical rankings are assigned to quality ranks (with A = 7, AB = 6, B = 5, etc., and no rank =0) the mean quality rank for the 12 relevés was 3.5 (Table 19).

Comparison of study sites:

Once data were compiled, each study site was ranked based on both number of SGCN animal species found and number of target animal species found. It is worth noting that these sites represent areas where concentrations of rare species had been previously identified during the ASP I study and thus *may* all represent areas that already have high comparative concentrations of SGCN than areas around them. These are not randomly chosen study sites.

In the interest of examining trends in species distribution across the landscape, sites were grouped into three categories: "Tier-I," "Tier-II," and "Tier-III" (see "Survey Site Descriptions" section pages 14 – 17).

Sites-1, -2, -4, and -9 (all within Sherburne NWR) were all given Tier-I status because they had both the highest number of SGCN animal species (≥12) and highest number of target animal species (≥4) found within them. Sites-3, -5, -7, and -11 were given Tier-II status. At each Tier-II site, ≥ 3 target animal species and ≥ 8 SGCN animal species were documented. Sites-6, -8, -10 and -12 were given Tier-III status by having three or less target species found and ≤ 7 SGCN animal species (Table 19).

These ranked study sites were then compared to each other using habitat data obtained within each site to determine if patterns in site characteristics would be apparent. Summary data for each group of ranked sites follows

<u>"Tier-I" Sites-1, -2, -4 and -9:</u> These sites were characterized by minimal low woody plant cover, an average of 1.2% (range: 0% – 2.32%) and few overstory trees (less than one per site on average). These sites had a comparatively high percent of low graminoid cover an average of 46% (ranging from 30% up to 70%) and sparse tall graminoid cover (average 2.5%). Amounts of low herbaceous cover varied more than graminoid cover type, with an average of about 26%

but varying between 12% and 45%, with little to no tall herbaceous cover. No standing water was present within any site. Tier-I sites had very sparse litter cover, accounting for an average of only 1.6% of ground cover (ranging from 0% - 3.2%). Moderate levels of bare soil were consistent across all Tier-I sites: comprising 10% to 15% ground-cover (average: 13%). Moss cover type was variable across Tier-I sites, but averaged about 10.5% of cover, which is slightly more than either Tier II or III sites. Tier-I sites had mean vegetation heights averaging 441mm (17.5 inches). Soil type in all sites was classified as "Sand." Average number of gopher mounds per 100 m^2 of a study site was between 5/100 m^2 and 10/100 m^2 (with an average of 7/100 m^2) for Tier-I sites, which was similar to sites in Tiers II and III. No site contained significant rock features, and "Tier-I" sites also little or no course woody debris present.

"Tier-II" Sites-3,- 5, -7, -11: These sites were characterized by low to moderate levels of low (average of 5.5% cover) and tall (average of 11% cover) woody plant cover and generally exhibited more woody plant cover than "Tier-I" sites. "Tier-II" sites typically had an average of 32% low graminoid plant cover (ranging from 25% - 40%) which was less than in Tier-I sites. Similar to Tier-I ranked sites; Tier-II ranked sites had little tall graminoid plant cover. Tier-II sites showed a tendency toward slightly less low herbaceous plant cover than Tier-I ranked sites, an average of about 18% (ranging from 9% and 35% of total cover). Again similar to Tier-I sites, Tier-II sites had sparse tall herbaceous plant cover and no standing water. Tier-II ranked sites had more litter cover than Tier-I ranked sites, an average of 5.6%, as well as more open soil, 18% on average. Amounts of moss type cover were fairly consistent between Tier-II and –III sites (average of 6% in Tier II sites and 6.2% in Tier III sites). Tier-II sites had higher mean vegetation heights than Tier-I ranked sites (470mm, 18.5 inches), Tier-II sites had more overstory trees (an average of 3 per site) than Tier-I sites, however these data were quite variable (0-11 per site). As stated above, mean number of gopher mounds per 100 m^2 was very slightly higher than in Tier-I sites (7.5/100 m^2), there were also more woody objects and more rocks present in Tier-II sites.

"Tier-III" Sites-6, -8, -10, -12-: These sites had more woody plant cover than Tier I sites and more low woody plant cover than Tier II sites (average of 8.8% low and 11.6% tall respectively). Low graminoid plant cover was similar to Tier–II ranked sites (an average of 31.7%). All sites were similar in having low levels of tall graminoid plant cover. Again, tall and low herbaceous plant cover was similar to both Tier-I and -II sites (an average of 17.7% cover).Tier III had the lowest average percent of low herbaceous cover at an average of 15%. Again there was no standing water. There was more litter cover in Tier-III than either other tier, 9.9% cover. Percent cover of bare earth (an average of 13%) was similar to Tier-I sites but less than Tier-II sites. Moss was comparable to amounts in Tier II sites (average of 6.2%) and slightly less than in Tier I sites. Tier III sites had an average vegetation height of 433mm (about 17 inches). Tier-III sites had an average density of overstory trees of 2 per site, but more consistently had overstory trees present than either Tier I or II sites. Tier-III sites also had a similar number of gopher mounds per 100 m^2 than both other site rankings, 8/100 m^2, but again had more consistently higher amounts of gopher mounds than sites in their of the other two tiers.

Discussion

Habitat Use and Characterization

The overarching goal of this study was to attempt to describe the general characteristics that may represent the highest quality habitat in the Anoka Sand Plain subsection for the rare species we targeted in this study. It is a well understood conservation principle that the best way to preserve multiple rare species is to understand and preserve their habitat (Franklin, 1993). The approach taken to better understand important habitat features in this study was to select areas where relatively high concentrations of rare animals had been documented during a previous study, conduct additional surveys and characterize the habitat features of those areas. Survey sites were chosen by surveyors with experience in this landscape as areas that had documented occurrences of one or more rare animal species. The 12 survey sites all represent good quality existing habitat (e.g., host a variety of rare prairie and oak savanna species) on the Anoka Sand Plain. Some sites are within the context of a large expanse of undeveloped and non-agricultural land, and some are fragments of existing habitat within a State Forest between and around stands of planted pines.

In an attempt to further examine habitat features potentially important to our target species, the 12 study sites were divided into three tiers based on the number of targeted species and total SGCN species documented at each site, and then each tier of sites was examined.

The Tier I sites, which had the highest number of SGCN and target species, tended to have the highest number of native plant species (both forbs and graminoids). Although none of the sites had much tall cover (herbaceous, graminoid, or woody), the Tier I sites tended to have the least amount of tall cover. The Tier I sites also tended to have higher relevé rankings than the Tier II and III sites. Whereas all of the Tier III sites and two of the Tier II sites had scattered pines throughout the larger opening in which they occurred, none of the Tier I sites did.

Five habitat components, woody vegetation, litter cover, low herbaceous cover, low graminoid cover and moss cover, appeared most indicative of a site's Tier designations. Tier I sites, which supported the most SGCN and target animals, tended to have less woody vegetation and litter cover, and more low herbaceous cover, low graminoid cover and moss than Tier II and III sites. Although bare soil did not clearly tie well into Tier designation at this time, the presence of patches of open sandy soil was identified as the primary habitat characteristic for most Anoka Sand Plain SGCN in our earlier project ASP I (Harper et al., 2009) and the average cover was never less than 13% at any of the 12 study sites. Although it was not directly measured by this study bunch forming (vs. sod forming) native prairie grasses appear to be an important structural habitat component of some Tier I and Tier II sites (pers. Obs).

Some of these cover type findings discussed above support the personal observations of the researchers on this project that sites which are more diverse in micro-habitat structure appear to host a greater number of SGCN and target species. This was not an observation directly measured by the data collected during this project; however the presence of bunch forming native prairie grasses and higher amounts of herbaceous plant cover appeared to contribute to greater micro habitat structure diversity at Tier I and some Tier II sites (pers. obs).

During the ASP I project GIS analysis at the landscape scale showed a trend toward sites with the largest total amount of open habitat having the most SGCN species. In this study, three of the Tier III sites where part of the smallest prairie openings (2,750 m^2– 10,000 m^2) surveyed. Two of the Tier II sites were in very large prairie openings (100,000 – 200,000 m^2). Prairie openings that included the four Tier I sites ranged from 32,000 – 60,000 m^2. This suggests that there may be an optimal size of prairie opening that provides a large enough area of low vegetation that is still in relatively close proximity to other habitats. This is an area for future research to help inform habitat management.

Several landscape level observations of habitat quality have direct links to decisions made when managing land. Connectivity to the larger landscape context of multiple key habitat types appears to be an important theme in predicting areas of greater SGCN diversity. Some of the least diverse sites were those that were areas of open, less complex plant communities and micro-habitats surrounded by very uniform large expanses of altered habitat (in this case pine plantations). It is possible that the reduced number of different habitats nearby to these sites rendered these sites less useable to some rare species.

Further evidence for the importance of a diverse landscape made up of different, nearby patches of structurally diverse habitat can be found in the examination of the western hog-nosed snake tracking study results. Snakes tracked in and around sites within Sand Dunes State Forest had larger home range sizes on average (for estimates using both MCP and KD methods) (Table 18). These data suggest that snakes must move further to access all habitat features that they need in a highly altered landscape. These types of extended movements between activity centers increase both stress on an animal and likelihood of anthropogenic and natural causes of mortality. While certain levels of mortality are a natural part of a healthy population, a species that is already confined to small patches of suitable habitat surrounded by unsuitable habitat can be further stressed beyond healthy limits by needing to make large frequent movements between patches. Additional research is warranted to elucidate whether or not statistically significant differences in home range size in marginal habitat exist for this species in the Anoka Sand Plain.

This observation in hog-nosed snakes may also partially explain why many other rare species are found less frequently in the state forest. Snakes have a relatively large dispersal ability compared to a plains pocket mouse or Leonard’s skipper, and the small isolated pockets of suitable habitat may be prohibitively isolated from one another for these species to use them. Stochastic events and simple limitation of space and resources may be some of the reasons that these sites appear to support less animal species.

Relationship between SGCN Habitat and Native Plant Communities:

One goal of this study was to determine whether there is a relationship between Anoka Sand Plain SGCN and native plant community (NPC) quality. As part of ASP I, relevés were placed in high quality oak savanna plant communities to document and describe these areas. These relevés can be used as benchmarks for high quality plant communities. One measure of native plant community quality is native plant species richness. When the relevés from the 12 study sites of this project were compared to those from ASP I, native plant species richness was considerably less in the 12 study sites (mean of 23.1 native species, Table 19) than those placed in 11 oak savanna sites during ASP I (mean of 46.6) (Table 20). Another measure of native plant community quality is the element occurrence quality ranks (A-D). When numerical rankings are assigned to native plant communities as described in appendix II, the mean NPC quality rank for the oak savanna relevés during ASP I was 4.27, higher than the mean of 3.5 for the 12 sites in this study.

One might conclude that the quality of the oak savanna native plant community is not a highly important factor in habitat for these SGCNs. However, many invertebrate SGCN require the presence of certain native plants. The hairy grama, roundheaded bush clover, large flowered penstemon, and blazing stars are necessary components of the plant community for the rare invertebrates targeted in this study. There were some relationships observed between the targeted plant species and invertebrate SGCN. All four sites where Leonard's skipper was found had blazing star species, which are important nectar sources for this skipper. All five sites where *Metaphidippus arizonensis* were found had round-headed bush clover in them and two had large-flowered penstemon; the old seed heads of these two plants are used as nest sites by *M. arizonensis*. The absence of *Tutelina formicaria* from the study sites does not appear to be related to availability of nest sites, since they also utilize old seeds of these two plant species. Similarly, while three sites contained fairly large populations of hairy grama, no Uncas skippers were found, indicating that availability of the larval host plant is not likely the cause of the skipper's apparent extirpation from the area.

It is also possible that the quality of oak savanna native plant communities is somewhat indicative of the structural complexity present in the habitat, something which, although not directly measure by this project, may be important in predicting SGCN distribution across the landscape.

Western hog-nosed snake tracking

While the main objective of this project was to assess habitat use among rare species of the Anoka Sand Plain subsection, a secondary product of this study was the assessment of the usefulness of a novel tracking technology (HR) for the small fossorial western hog-nosed snake.

Harmonic radar tracking technology was tested as a way to track western hog-nosed snakes given their small size. One of the reasons that the habitat needs of this species are poorly understood in Minnesota is that a large portion of individuals in a given population are typically too small to use traditional radio tracking technology methods. In order to maximize sample size and duration of study we decided to test the use of harmonic radar for tracking western hog-nosed snakes.

During the first year of this project (the summer of 2010), snakes were only tracked using harmonic radar tracking technology. The small size, low weight and low cost of the harmonic radar tracking tags proved to be excellent features for use with this species, and efficient manufacturing and surgical implantation techniques were quickly developed. It was noted early on in the research and development phases of harmonic radar use that the tags had more limited detection distances than traditional VHF transmitters, but range was deemed satisfactory in tests given the perceived small home ranges of the western hog-nosed snakes. In 2010, 13 snakes were given harmonic radar tags and tracked. As surveyors became comfortable with the new technology, and confident in their interpretation of the signals in the field, it was noted that detection distances were consistently below those observed in pre-implantation practice. Throughout the course of the study it was determined that the snake's occasionally fossorial nature, the proximity of the surgically implanted tags to the snake's dense bodies, and tag design were the chief causes for this reduced functional detection distance. Despite this reduced distance, most snakes were detected regularly once methodology was refined. Although snakes were detected regularly in home range areas similar to those expected, a portion of tracking sessions for each animal would yield no location, no signal would be detected and the animal would go unfound. Since animals were always re-discovered relatively nearby it was hypothesized by surveyors that snakes were either using refugia too deep to be detected, moving outside of a reasonably searched area, or other factors such as body position were negatively affecting detectability.

In order to test the assumptions made during the 2010 field season about why harmonic radar tracking tags were sometimes going undetected, we incorporated VHF radio telemetry into the study. These transmitters were small enough to place into the largest individuals but would only last for a single field season. Through the use of these VHF transmitters it was discovered that the hypothesis regarding the use of deep refugia was incorrect. Snakes were making much larger and more frequent above ground movements than previously thought, and the main reason for failed searches was most likely that the animal had moved out of range of the harmonic radar tracking system and outside a reasonable search area given time constraints. This observation was supported in post-survey data analysis when home range estimates using harmonic radar were compared to those obtained using VHF data. Harmonic radar home range estimates were found to be significantly smaller for all estimated home range sizes (Table 18). In addition, harmonic radar did not reveal the whole picture of movement patterns in this species. Thus it is our determination that harmonic radar is not a viable option for home range studies for this species. However, harmonic radar was useful for improving the detectability of this highly cryptic species. It is our opinion that the data obtained by harmonic radar tracking technology can still be used to examine western hog-nosed snake movement and habitat use while the snakes are in activity centers, and the increased detectability while in these areas makes studies using the harmonic radar superior to studies using only visual encounter surveys, especially when surveyors have little experience in the detection of this species.

Management recommendations

The presence of patches of open sandy soil was identified as the primary habitat characteristic for most Anoka Sand Plain SGCN in our earlier project ASP I (Harper et al., 2009). The presence of pocket gophers was discussed as important for helping to create some of these patches of open sand areas. The GIS analysis in that study showed a trend toward sites with the largest total amount of open habitat having the most SGCN species. The results of this study suggests that relatively large open areas dominated by a diversity of low graminoid and herbaceous native species with minimal tree cover support the suite of rare species targeted in this study. For the rare invertebrates targeted in this study, it is also beneficial to have specific native plant species, including large-flowered penstemon, round-headed bush clover, and species of blazing stars. A variety of nectar-producing forbs are also important for butterflies and skippers.

These habitat features can be encouraged through a number of management practices. Prescribed burning is one useful tool for habitat management when used appropriately.

Although fire is a necessary and natural disturbance regime in these habitats when not done carefully and at the correct time of year it can be detrimental to all animal taxa, but especially to invertebrates and herps. Prescribed burns should be limited to portions of habitat, especially in areas known to harbor rare invertebrates. When a burn is planned for a specific area, a segment of the area should be left unburned to provide refugia for sessile or small limited mobility species. If this is not done, entire local populations can be extirpated or severely impacted long term. Burning during animals' most active migration and reproductive seasons should be avoided. Burns should be conducted during winter months, as winter burns are the least detrimental to many animals. Midwest Partners in Amphibian and Reptile Conservation recommend burning between November 1 and March 1 with burns after April 1 being discouraged unless the burn day is cloudy and below 10 ˚C (50 ˚F) (see Appendix III for details on burn recommendations). The best way to conduct burns is to have good quality recent information on the species using the planned burn area (including knowledge of hibernacula, nests or invertebrate host plants in the area) and knowledge of how those species respond to proposed burn plans. Although burns need to be done deliberately and with care, they will help promote native plant species and reduce cover by non-native invasive sod-forming grasses.

Another technique to employ when encouraging complex native communities is control of invasive woody plants, non-native honeysuckle, and planted pines. This control will reduce shade and provide more room for a diverse array of graminoids and forbs. An additional variable to consider when managing or restoring prairie/savanna communities is the importance of patches of open soil. While planting native plants is an important tool in restoring these communities, some areas of bare soil should be maintained.

This study focused on potential "hot-spots" of rare species occurrence with hopes of better understanding and describing these concentrations of rare animal species. When hot-spots are documented they often represent breeding, feeding, or overwintering locations that are essential to the persistence of these rare species on the landscape. These periods in the life cycle of many SGCN are times when biological imperatives (reproduction) or survival strategies (winter hibernation) leave them vulnerable. Management in these areas (prescribed burns, logging or cutting, construction, and trail maintenance) should carefully consider that these areas are being used by a variety of species during several critical life stages. Planned management activities wherever SGCN and native plant communities are present should seek to maintain, enhance or restore well-functioning native ecosystems and to replicate the natural processes that have historically been part of these systems.

Mowing is another useful tool in maintaining open soil and structural complexity, and is one often necessary in public recreation areas. Managers should take care to avoid removing invertebrate species host plants at critical times such as when flowers are present for nectaring when mowing (timing may vary by invertebrate species of conservation concern). Mowing should also be avoided during early to mid - spring in areas where ground nesting birds (such as Lark sparrows) are nesting and in fall (August and September) in areas where snake, lizard and turtle hatchlings are emerging. Mowing during the late fall and winter is preferred if snow depth is not prohibitive.

Conservation Concerns

During the course of both this project and the previous ASP I project it was observed that larger paved roads that bisect expanses of SGCN habitat appear to be sources high mortality for multiple species but especially for reptiles and amphibians. During the spring and fall, snakes, turtles and various species of amphibians (salamanders and frogs) migrate to and from overwintering locations and active season areas. These movements frequently necessitate the crossing of a large busy road in the increasingly developed and populated Anoka Sand Plain. Decreased speed limits, speed bumps, seasonal road closures, and signage (see Appendix IV) are all techniques that can help mitigate this source of mortality where roads fragment otherwise continuous landscapes. Turtles are an animal group that because of their long lives, and delayed sexual maturation, is especially vulnerable to adult members being removed from the population via road mortality. Roads may also fragment otherwise contiguous habitat for very small species with low dispersal abilities.

Another threat facing several reptile species at these sites is “take” for personal and commercial uses. Some western hog-nosed snakes and gophersnakes are legally collected from Sand Dunes State Forest (Anonymous Commercial Collectors, pers. comm.), and we have reason to believe animals are being illegally collected from Sherburne National Wildlife Refuge. Some other species targeted by collectors are smooth green snakes, garter snakes of both species and Blanding’s turtles (although collection of this state listed Threatened species is illegal in any location). Diligent enforcement of collection prohibition and seasonal off trail use prohibitions by refuge (and other protected area) visitors is necessary to help control this issue.

Throughout the course of this study and the ASP I project, a large number of human subsidized mesopredators were observed. An abundance of these species (coyotes, skunks, raccoons, badgers, and others) can significantly reduce the reproductive success of the species they prey upon. Mesopredators were noted to be extremely common in Sherburne NWR, Sand Dunes State Forest, and Uncas Dunes SNA. The observation of large numbers of these mesopredators, coupled with the large number of scavenged turtle nests we observed during this study, indicates that a reduction in mesopredator numbers at Sherburne NWR and Sand Dunes State Forest may benefit turtle species, including Blanding’s turtles (See appendix V). Specifically the Blanding’s turtles in these areas appear to currently have very limited population recruitment (pers. obs.).

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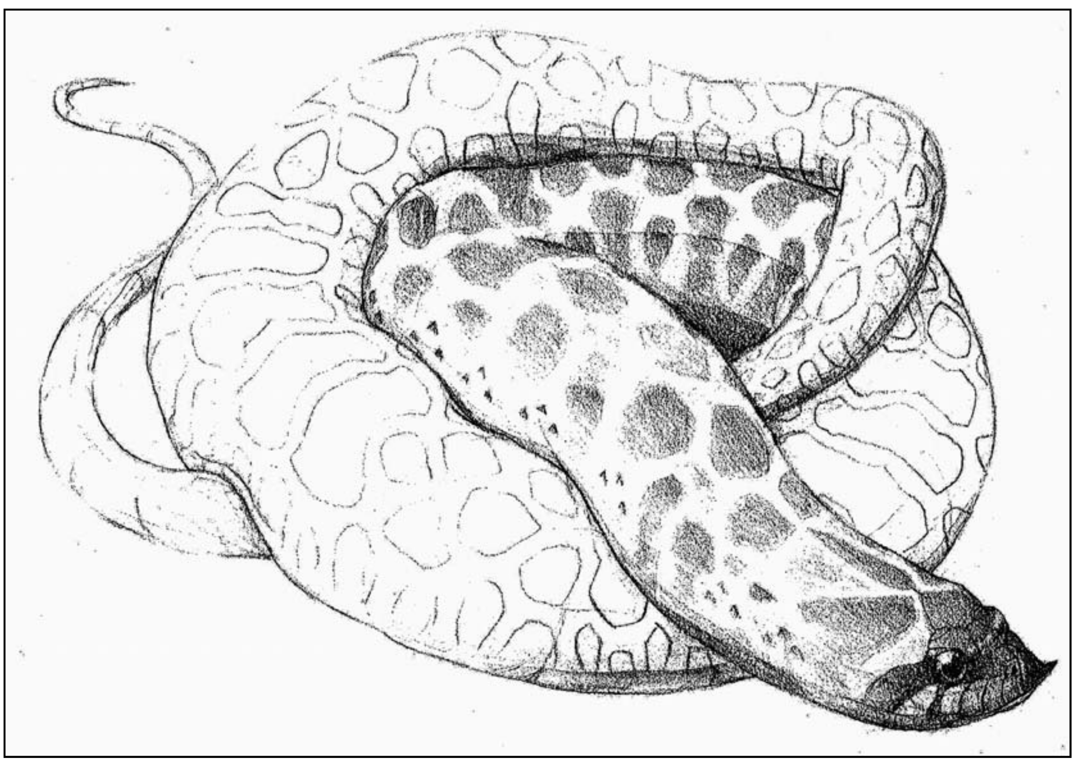

Tables and Figures

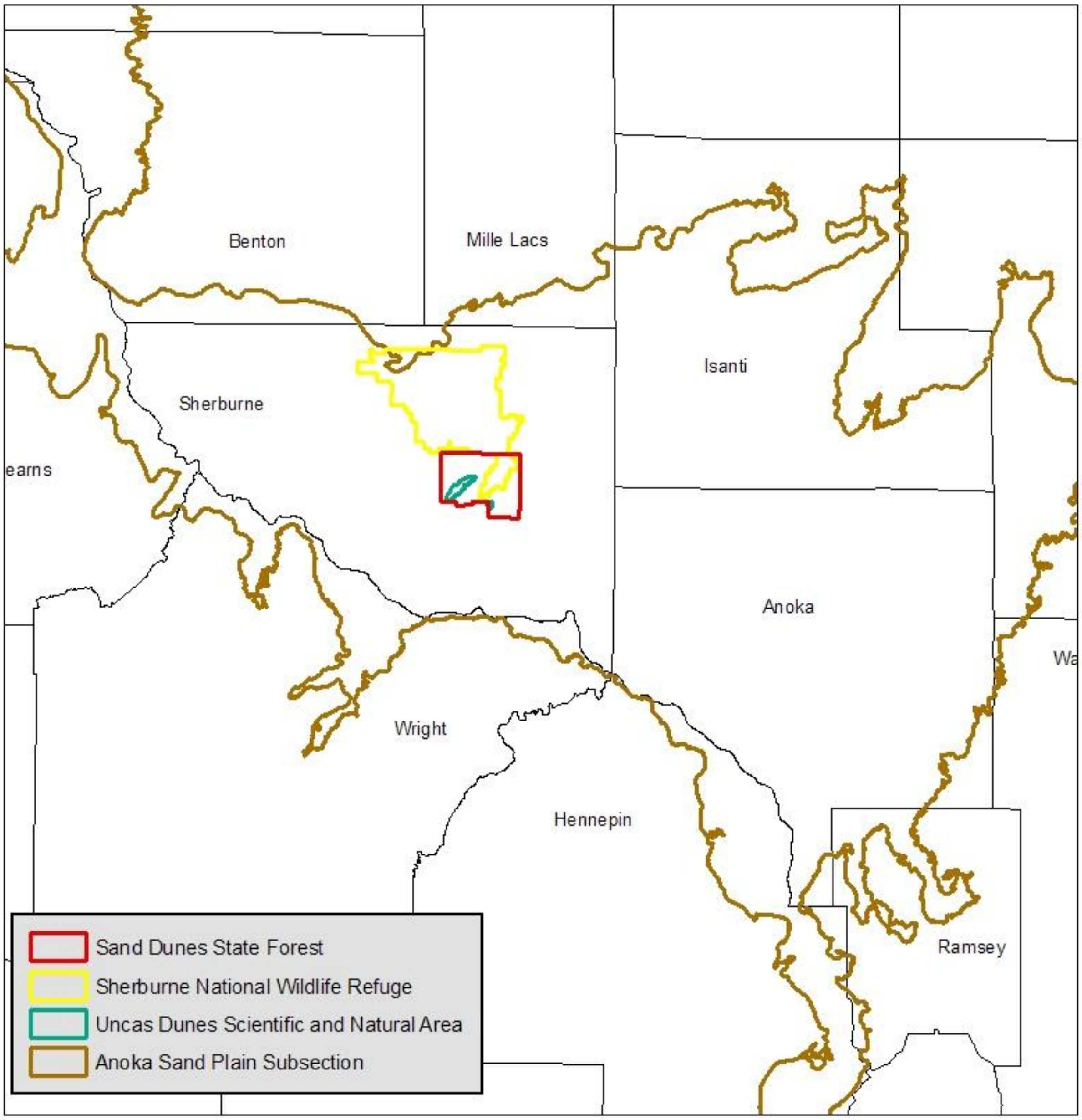

Figure 1. Location of the target managed area survey sites on the Anoka Sand Plain subsection.

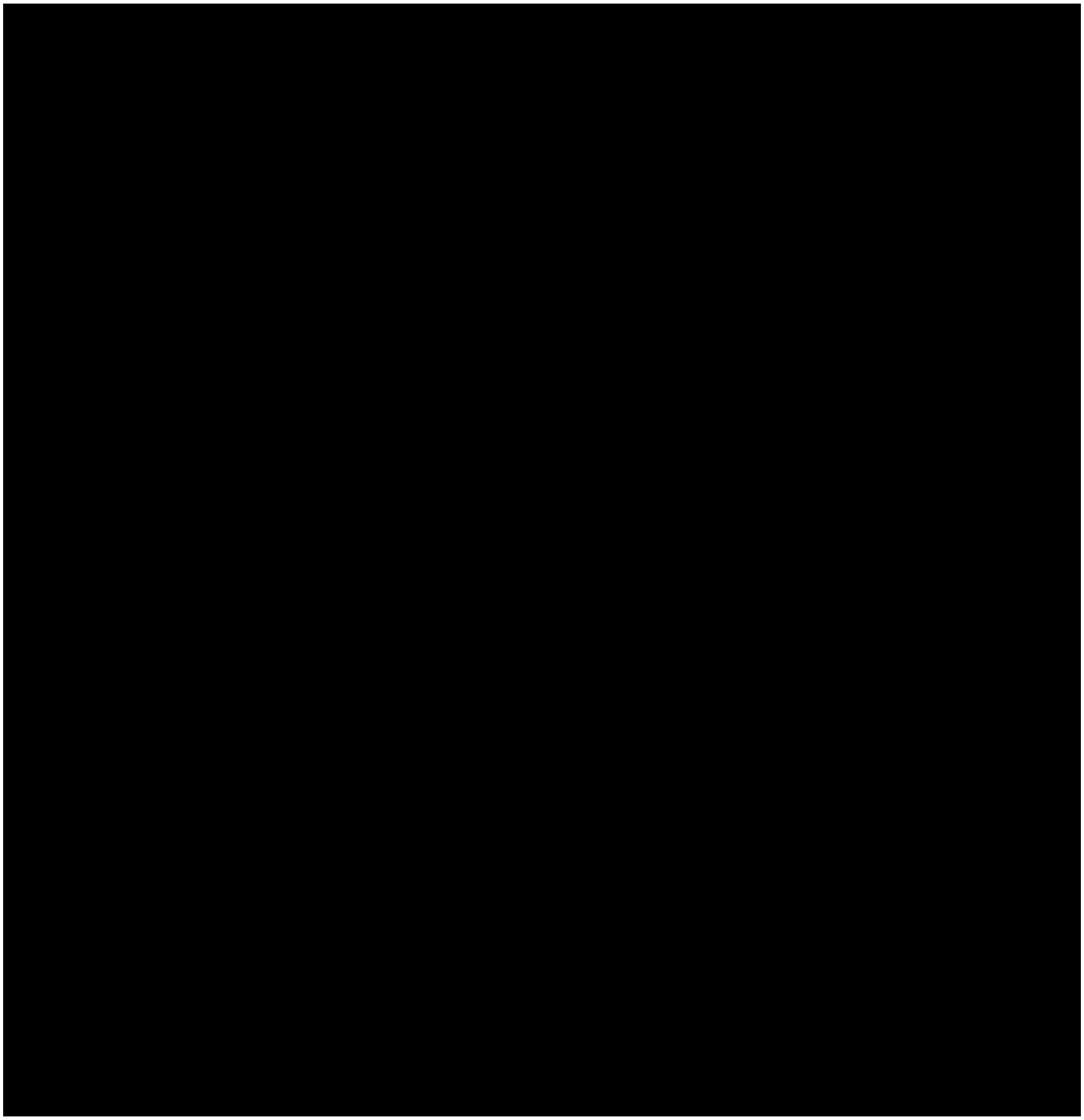

Figure 2. Locations of the 12 survey sites chosen for this project within Sherburne National Wildlife Refuge and Sand Dunes State Forest (Including Uncas Dunes Scientific and Natural Area).

Figure 3a. PIT tag implantation in a western hog-nosed snake. ©Amber Sue Moher

Figure 3b. Tracking western hog-nosed snakes with harmonic radar receiver. ©MN DNR Margaret Edwards

Figure 3c. One of the 12 study sites visited during this study. ©MN DNR Erica Hoaglund

Tables

Table 1. Target animal species in greatest conservation need (SGCN). Species recorded at study sites during project period highlighted in gray.

Table 1. Target Animal Species of Greatest Conservation Need* (Species documented at study sites highlighted in grey)				
Taxa	**Scientific Name**	**Common Name**	**State Status**	**Federal Status**
Mammals	*Perognathus flavescens*	Plains Pocket Mouse	SPC	NL
Birds	*Ammodramus savannarum*	Grasshopper Sparrow	NL	NL
Birds	*Caprimulgus vociferus*	Whip-poor-will	NL	NL
Birds	*Chordeiles minor*	Common Nighthawk	NL	NL
Birds	*Dolichonyx oryzivorus*	Bobolink	NL	NL
Birds	*Lanius ludovicianus*	Loggerhead Shrike	THR	NL
Birds	*Melanerpes erythrocephalus*	Red-headed Woodpecker	NL	NL
Birds	*Strunella magna*	Eastern Meadowlark	NL	NL
Reptiles	*Heterodon nasicus*	Western Hognose Snake	SPC	NL
Inverts	*Cicindela lepida*	Little While Tiger Beetle	THR	NL
Inverts	*Cicindela patruela paturela*	Northern Barrens Tiger Beetle	SPC	NL
Inverts	*Hesperia leonardus leonardus*	Leonard's Skipper	SPC	NL
Inverts	*Hesperia uncas*	Uncas Skipper	END	NL
Inverts	*Metaphidippus arizonensis*	A Jumping Spider	SPC	NL
Inverts	*Tutelina formicaria*	A Jumping Spider	SPC	NL
*Lark Sparrow is proposed to become a state listed special concern species so will be				

Table 2a. Mammal species documented at study sites during project period. Target species are highlighted in gray.

Common Name	Scientific Name	State List Status	Federal List Status	SGCN
Northern Short-tailed Shrew	*Blarina brevicauda*	NL	NL	N
Masked Shrew	*Sorex cinereus*	NL	NL	N
Meadow Vole	*Microtus pennsylvanicus*	NL	NL	N
Plains Pocket Mouse	*Perognathus flavescens*	SPC	NL	Y
Prairie Deer Mouse	*Peromyscus maniculatus bairdii*	NL	NL	N
Thirteen-lined Ground Squirrel	*Spermophilus tridecemlineatus*	NL	NL	N
White-footed Mouse	*Peromyscus leucopus*	NL	NL	N

Table 2b. Bird species documented at study sites during project period. Target species are highlighted in gray.

Species Group	Common Name	Scientific Name	State List Status	Federal List Status	SGCN
Birds	American Crow	*Corvus brachyrhynchos*	NL	NL	N
Birds	American Goldfinch	*Carduelis tristis*	NL	NL	N
Birds	American Kestrel	*Falco sparverius*	NL	NL	N
Birds	American Redstart	*Setophaga ruticilla*	NL	NL	N
Birds	American Robin	*Turdus migratorius*	NL	NL	N
Birds	Bald Eagle	*Haliaeetus leucocephalus*	SPC	THR	Y
Birds	Baltimore Oriole	*Icterus galbula*	NL	NL	N
Birds	Barn Swallow	*Hirundo rustica*	NL	NL	N
Birds	Black-and-White Warbler	*Mniotilta varia*	NL	NL	N
Birds	Black-capped Chickadee	*Poecile atricapillus*	NL	NL	N
Birds	Blue Jay	*Cyanocitta cristata*	NL	NL	N
Birds	Blue-winged Warbler	*Vermivora pinus*	NL	NL	Y
Birds	Brown Thrasher	*Toxostoma rufum*	NL	NL	Y
Birds	Brown-headed Cowbird	*Molothrus ater*	NL	NL	N
Birds	Cedar Waxwing	*Bombycilla cedrorum*	NL	NL	N
Birds	Chipping Sparrow	*Spizella passerina*	NL	NL	N
Birds	Clay-Colored Sparrow	*Spizella pallida*	NL	NL	N
Birds	Common Loon	*Gavia immer*	NL	NL	Y
Birds	Common Nighthawk	*Chordeiles minor*	NL	NL	Y
Birds	Common Raven	*Corvus corax*	NL	NL	N
Birds	Common Yellowthroat	*Geothlypis trichas*	NL	NL	N
Birds	Cooper's Hawk	*Accipiter cooperii*	NL	NL	N
Birds	Dickcissel	*Spiza americana*	NL	NL	Y
Birds	Downy Woodpecker	*Picoides pubescens*	NL	NL	N
Birds	Eastern Bluebird	*Sialia sialis*	NL	NL	N
Birds	Eastern Kingbird	*Tyrannus tyrannus*	NL	NL	N
Birds	Eastern Meadowlark	*Sturnella magna*	NL	NL	Y
Birds	Eastern Phoebe	*Sayornis phoebe*	NL	NL	N
Birds	Eastern Towhee	*Pipilo erythrophthalmus*	NL	NL	N
Birds	Eastern Wood Pewee	*Contopus virens*	NL	NL	Y
Birds	Field Sparrow	*Spizella pusilla*	NL	NL	Y
Birds	Golden-winged Warbler	*Vermivora chrysoptera*	NL	NL	Y
Birds	Grasshopper Sparrow	*Ammodramus savannarum*	NL	NL	Y
Birds	Gray Catbird	*Dumetella carolinensis*	NL	NL	N
Birds	Great Blue Heron	*Ardea herodias*	NL	NL	N
Birds	Great Crested Flycatcher	*Myiarchus crinitus*	NL	NL	N
Birds	Hairy Woodpecker	*Picoides villosus*	NL	NL	N
Birds	House Wren	*Troglodytes aedon*	NL	NL	N
Birds	Indigo Bunting	*Passerina cyanea*	NL	NL	N
Birds	Killdeer	*Charadrius vociferus*	NL	NL	N
Birds	Lark Sparrow	*Chondestes grammacus*	NL	NL	N
Birds	Least Flycatcher	*Empidonax minimus*	NL	NL	Y
Birds	Mallard	*Anas platyrhynchos*	NL	NL	N
Birds	Mourning Dove	*Zenaida macroura*	NL	NL	N
Birds	Northern Cardinal	*Cardinalis cardinalis*	NL	NL	N
Birds	Northern Flicker	*Colaptes auratus*	NL	NL	N
Birds	Northern Harrier	*Circus cyaneus*	NL	NL	Y
Birds	Olive-sided Flycatcher	*Contopus cooperi*	NL	NL	Y
Birds	Ovenbird	*Seiurus aurocapilla*	NL	NL	Y
Birds	Pileated Woodpecker	*Dryocopus pileatus*	NL	NL	N
Birds	Red-bellied Woodpecker	*Melanerpes carolinus*	NL	NL	N
Birds	Red-breasted Nuthatch	*Sitta canadensis*	NL	NL	N
Birds	Red-eyed Vireo	*Vireo olivaceus*	NL	NL	N
Birds	Red-tailed Hawk	*Buteo jamaicensis*	NL	NL	N
Birds	Red-winged Blackbird	*Agelaius phoeniceus*	NL	NL	N
Birds	Ring-necked Pheasant	*Phasianus colchicus*	NL	NL	N
Birds	Rose-breasted Grosbeak	*Pheucticus ludovicianus*	NL	NL	Y
Birds	Sandhill Crane	*Grus canadensis*	NL	NL	N
Birds	Scarlet Tanager	*Piranga olivacea*	NL	NL	N
Birds	Sedge Wren	*Cistothorus platensis*	NL	NL	Y
Birds	Song Sparrow	*Melospiza melodia*	NL	NL	N
Birds	Trumpeter Swan	*Cygnus buccinator*	THR	NL	Y
Birds	Turkey Vulture	*Cathartes aura*	NL	NL	N
Birds	Veery	*Catharus fuscescens*	NL	NL	Y
Birds	Vesper Sparrow	*Pooecetes gramineus*	NL	NL	N
Birds	Warbling Vireo	*Vireo gilvus*	NL	NL	N
Birds	Whip-poor-will	*Caprimulgus vociferus*	NL	NL	Y
Birds	White-breasted Nuthatch	*Sitta carolinensis*	NL	NL	N
Birds	Wild Turkey	*Meleagris gallopavo*	NL	NL	N
Birds	Wilson's/Common Snipe	*Gallinago* sp.	NL	NL	N
Birds	Wood Duck	*Aix sponsa*	NL	NL	N
Birds	Yellow Warbler	*Dendroica petechia*	NL	NL	N
Birds	Yellow-throated Vireo	*Vireo flavifrons*	NL	NL	N

Table 2c. Herp species documented at study sites during project period. Target species are highlighted in gray.

Common Name	Scientific Name	State List Status	Federal List Status	SGCN
Blue-spotted Salamander	*Ambystoma laterale*	NL	NL	N
Blanding's Turtle	*Emydoidea blandingii*	THR	NL	Y
Boreal Chorus Frog	*Pseudacris maculata*	NL	NL	N
Common Gartersnake	*Thamnophis sirtalis*	NL	NL	N
Gophersnake	*Pituophis catenifer*	SPC	NL	Y
Northern Leopard Frog	*Lithobates (Rana) pipiens*	NL	NL	N
Plains Gartersnake	*Thamnophis radix*	NL	NL	N
Smooth Greensnake	*Opheodrys vernalis*	NL	NL	N
Western Hog-nosed Snake	*Heterodon nasicus*	SPC	NL	Y

Table 2d. Invert species documented at study sites during project period. Target species are highlighted in gray.

Common Name	Scientific Name	State List Status	Federal List Status	SGCN
A Jumping Spider	*Metaphidippus arizonensis*	SPC	NL	Y
Big Sand Tiger Beetle	*Cicindela formosa*	NL	NL	N
Eastern Tailed-Blue Butterfly	*Everes comyntas*	NL	NL	N
Festive Tiger Beetle	*Cicindela scutellaris*	NL	NL	N
Leonard's Skipper	*Hesperia leonardus leonardus*	SPC	NL	Y
Long-dash Skipper	*Polites mystic*	NL	NL	N
Northern Barrens Tiger Beetle	*Cicindela paturela paturela*	SPC	NL	Y
Variegated Fritillary	*Euptoieta claudia*	NL	NL	N

Table 3. Species encountered at study site 1 during project period. Target species are highlighted in gray.

Species Group	Common Name	Scientific Name
Mammals	Plains Pocket Mouse	*Perognathus flavescens*
Birds	American Crow	*Corvus brachyrhynchos*
Birds	American Goldfinch	*Carduelis tristis*
Birds	American Robin	*Turdus migratorius*
Birds	Bald Eagle	*Haliaeetus leucocephalus*
Birds	Baltimore Oriole	*Icterus galbula*
Birds	Barn Swallow	*Hirundo rustica*
Birds	Blue Jay	*Cyanocitta cristata*
Birds	Brown Thrasher	*Toxostoma rufum*
Birds	Brown-headed Cowbird	*Molothrus ater*
Birds	Cedar Waxwing	*Bombycilla cedrorum*
Birds	Chipping Sparrow	*Spizella passerina*
Birds	Clay-colored Sparrow	*Spizella pallida*
Birds	Common Nighthawk	*Chordeiles minor*
Birds	Common Yellowthroat	*Geothlypis trichas*
Birds	Dickissel	*Spiza americana*
Birds	Downy Woodpecker	*Picoides pubescens*
Birds	Eastern Kingbird	*Tyrannus tyrannus*
Birds	Eastern Meadowlark	*Sturnella magna*
Birds	Eastern Phoebe	*Sayornis phoebe*
Birds	Eastern Towhee	*Pipilo erythrophthalmus*
Birds	Eastern Wood Pewee	*Contopus virens*
Birds	Field Sparrow	*Spizella pusilla*
Birds	Grasshopper Sparrow	*Ammodramus savannarum*
Birds	Great Blue Heron	*Ardea herodias*
Birds	Indigo Bunting	*Passerina cyanea*
Birds	Northern Flicker	*Colaptes auratus*
Birds	Red-bellied Woodpecker	*Melanerpes carolinus*
Birds	Red-eyed Vireo	*Vireo olivaceus*
Birds	Red-winged Blackbird	*Agelaius phoeniceus*
Birds	Ring-necked Pheasant	*Phasianus colchicus*
Birds	Sandhill Crane	*Grus canadensis*
Birds	Scarlet Tanager	*Piranga olivacea*
Birds	Vesper Sparrow	*Pooecetes gramineus*
Birds	Warbling Vireo	*Vireo gilvus*
Birds	Whip-poor-will	*Caprimulgus vociferus*
Birds	Yellow Warbler	*Dendroica petechia*
Birds	Yellow-throated Vireo	*Vireo flavifrons*
Herps	Boreal Chorus Frog	*Pseudacris maculata*
Herps	Common Gartersnake	*Thamnophis sirtalis*
Herps	Gophersnake	*Pituophis catenifer*
Herps	Smooth Greensnake	*Opheodrys vernalis*
Herps	Western Hog-nosed Snake	*Heterodon nasicus*
Inverts	A Jumping Spider	*Metaphedippus arizonensis*
Inverts	Big Sand Tiger Beetle	*Cicindela formosa*
Inverts	Eastern Tailed-Blue Butterfly	*Everes comyntas*
Inverts	Festive Tiger Beetle	*Cicindela scutellaris*

Table 4. Species encountered at study site 2 during project period. Target species are highlighted in gray.

Species Group	Common Name	Scientific Name
Mammals	Plains Pocket Mouse	*Perognathus flavescens*
Birds	American Crow	*Corvus brachyrhynchos*
Birds	American Goldfinch	*Carduelis tristis*
Birds	American Robin	*Turdus migratorius*
Birds	Bald Eagle	*Haliaeetus leucocephalus*
Birds	Baltimore Oriole	*Icterus galbula*
Birds	Barn Swallow	*Hirundo rustica*
Birds	Blue Jay	*Cyanocitta cristata*
Birds	Blue-winged Warbler	*Vermivora pinus*
Birds	Brown-headed Cowbird	*Molothrus ater*
Birds	Cedar Waxwing	*Bombycilla cedrorum*
Birds	Common Loon	*Gavia immer*
Birds	Common Yellowthroat	*Geothlypis trichas*
Birds	Dickcissel	*Spiza americana*
Birds	Eastern Bluebird	*Sialia sialis*
Birds	Eastern Kingbird	*Tyrannus tyrannus*
Birds	Eastern Towhee	*Pipilo erythrophthalmus*
Birds	Field Sparrow	*Spizella pusilla*
Birds	Golden-winged Warbler	*Vermivora chrysoptera*
Birds	Grasshopper Sparrow	*Ammodramus savannarum*
Birds	Gray Catbird	*Dumetella carolinensis*
Birds	Indigo Bunting	*Passerina cyanea*
Birds	Killdeer	*Charadrius vociferus*
Birds	Lark Sparrow	*Chondestes grammacus*
Birds	Least Flycatcher	*Empidonax minimus*
Birds	Meadlowlark species	*Sturnella x*
Birds	Mourning Dove	*Zenaida macroura*
Birds	Northern Flicker	*Colaptes auratus*
Birds	Olive-sided Flycatcher	*Contopus cooperi*
Birds	Pileated Woodpecker	*Dryocopus pileatus*
Birds	Red-winged Blackbird	*Agelaius phoeniceus*
Birds	Ring-necked Pheasant	*Phasianus colchicus*
Birds	Scarlet Tanager	*Piranga olivacea*
Birds	Vesper Sparrow	*Pooecetes gramineus*
Birds	Wood Duck	*Aix sponsa*
Birds	Yellow Warbler	*Dendroica petechia*
Birds	Yellow-throated Vireo	*Vireo flavifrons*
Herps	Blanding's Turtle	*Emydoidea blandingii*
Herps	Boreal Chorus Frog	*Pseudacris maculata*
Herps	Common Gartersnake	*Thamnophis sirtalis*
Herps	Gophersnake	*Pituophis catenifer*
Herps	Smooth Greensnake	*Opheodrys vernalis*
Herps	Western Hog-nosed Snake	*Heterodon nasicus*
Inverts	A Jumping Spider	*Metaphidippus arizonensis*
Inverts	Big Sand Tiger Beetle	*Cicindela formosa*

Table 5. Species encountered at study site 3 during project period. Target species are highlighted in gray.

Species Group	Common Name	Scientific Name
Mammals	Meadow Vole	*Microtus pennsylvanicus*
Mammals	Prairie Deer Mouse	*Peromyscus maniculatus bairdii*
Birds	American Crow	*Corvus brachyrhynchos*
Birds	American Goldfinch	*Carduelis tristis*
Birds	American Robin	*Turdus migratorius*
Birds	Bald Eagle	*Haliaeetus leucocephalus*
Birds	Baltimore Oriole	*Icterus galbula*
Birds	Blue Jay	*Cyanocitta cristata*
Birds	Brown-headed Cowbird	*Molothrus ater*
Birds	Chipping Sparrow	*Spizella passerina*
Birds	Common Loon	*Gavia immer*
Birds	Common Yellowthroat	*Geothlypis trichas*
Birds	Eastern Bluebird	*Sialia sialis*
Birds	Eastern Kingbird	*Tyrannus tyrannus*
Birds	Eastern Meadowlark	*Sturnella magna*
Birds	Eastern Towhee	*Pipilo erythrophthalmus*
Birds	Eastern Wood Pewee	*Contopus virens*
Birds	Field Sparrow	*Spizella pusilla*
Birds	Grasshopper Sparrow	*Ammodramus savannarum*
Birds	Gray Catbird	*Dumetella carolinensis*
Birds	Great Crested Flycatcher	*Myiarchus crinitus*
Birds	Indigo Bunting	*Passerina cyanea*
Birds	Mallard	*Anas platyrhynchos*
Birds	Mourning Dove	*Zenaida macroura*
Birds	Northern Flicker	*Colaptes auratus*
Birds	Pileated Woodpecker	*Dryocopus pileatus*
Birds	Red-winged Blackbird	*Agelaius phoeniceus*
Birds	Ring-necked Pheasant	*Phasianus colchicus*
Birds	Rose-breasted Grosbeak	*Pheucticus ludovicianus*
Birds	Sandhill Crane	*Grus canadensis*
Birds	Trumpeter Swan	*Cygnus buccinator*
Birds	Turkey Vulture	*Cathartes aura*
Birds	Yellow Warbler	*Dendroica petechia*
Birds	Yellow-throated Vireo	*Vireo flavifrons*
Herps	Gophersnake	*Pituophis catenifer*
Herps	Smooth Greensnake	*Opheodrys vernalis*
Herps	Western Hog-nosed Snake	*Heterodon nasicus*
Inverts	A Jumping Spider	*Metaphidippus arizonensis*

Table 6. Species encountered at study site 4 during project period. Target species are highlighted in gray.

Species Group	Common Name	Scientific Name
Mammals	Plains Pocket Mouse	*Perognathus flavescens*
Mammals	Prairie Deer Mouse	*Peromyscus maniculatus bairdii*
Mammals	Thirteen-lined Ground Squirrel	*Spermophilus tridecemlineatus*
Mammals	White-footed Mouse	*Peromyscus leucopus*
Birds	American Goldfinch	*Carduelis tristis*
Birds	Barn Swallow	*Hirundo rustica*
Birds	Black-capped Chickadee	*Poecile atricapillus*
Birds	Blue Jay	*Cyanocitta cristata*
Birds	Brown Thrasher	*Toxostoma rufum*
Birds	Brown-headed Cowbird	*Molothrus ater*
Birds	Common Loon	*Gavia immer*
Birds	Common Yellowthroat	*Geothlypis trichas*
Birds	Downy Woodpecker	*Picoides pubescens*
Birds	Eastern Kingbird	*Tyrannus tyrannus*
Birds	Eastern Towhee	*Pipilo erythrophthalmus*
Birds	Eastern Wood Pewee	*Contopus virens*
Birds	Field Sparrow	*Spizella pusilla*
Birds	Grasshopper Sparrow	*Ammodramus savannarum*
Birds	Gray Catbird	*Dumetella carolinensis*
Birds	Great Blue Heron	*Ardea herodias*
Birds	Northern Flicker	*Colaptes auratus*
Birds	Northern Harrier	*Circus cyaneus*
Birds	Red-winged Blackbird	*Agelaius phoeniceus*
Birds	Ring-necked Pheasant	*Phasianus colchicus*
Birds	Rose-breasted Grosbeak	*Pheucticus ludovicianus*
Birds	Sandhill Crane	*Grus canadensis*
Birds	Sedge Wren	*Cistothorus platensis*
Birds	Song Sparrow	*Melospiza melodia*
Birds	Vesper Sparrow	*Pooecetes gramineus*
Birds	Wild Turkey	*Meleagris gallopavo*
Birds	Wilson's/Common Snipe	*Gallinago sp.*
Birds	Yellow Warbler	*Dendroica petechia*
Herps	Blanding's Turtle	*Emydoidea blandingii*
Herps	Gophersnake	*Pituophis catenifer*
Herps	Northern Leopard Frog	*Lithobates (Rana) pipiens*
Herps	Western Hog-nosed Snake	*Heterodon nasicus*
Spiders	A Jumping Spider	*Metaphidippus arizonensis*
Inverts	Leonard's Skipper	*Hesperia leonardus leonardus*

Table 7. Species encountered at study site 5 during project period. Target species are highlighted in gray.

Species Group	Common Name	Scientific Name
Mammals	Plains Pocket Mouse	*Perognathus flavescens*
Birds	American Goldfinch	*Carduelis tristis*
Birds	American Robin	*Turdus migratorius*
Birds	Baltimore Oriole	*Icterus galbula*
Birds	Blue Jay	*Cyanocitta cristata*
Birds	Brown Thrasher	*Toxostoma rufum*
Birds	Brown-headed Cowbird	*Molothrus ater*
Birds	Cedar Waxwing	*Bombycilla cedrorum*
Birds	Chipping Sparrow	*Spizella passerina*
Birds	Common Loon	*Gavia immer*
Birds	Common Yellowthroat	*Geothlypis trichas*
Birds	Cooper's Hawk	*Accipiter cooperii*
Birds	Eastern Bluebird	*Sialia sialis*
Birds	Eastern Kingbird	*Tyrannus tyrannus*
Birds	Eastern Towhee	*Pipilo erythrophthalmus*
Birds	Eastern Wood Pewee	*Contopus virens*
Birds	Field Sparrow	*Spizella pusilla*
Birds	Gray Catbird	*Dumetella carolinensis*
Birds	Great Blue Heron	*Ardea herodias*
Birds	Great Crested Flycatcher	*Myiarchus crinitus*
Birds	House Wren	*Troglodytes aedon*
Birds	Indigo Bunting	*Passerina cyanea*
Birds	Lark Sparrow	*Chondestes grammacus*
Birds	Mourning Dove	*Zenaida macroura*
Birds	Red-winged Blackbird	*Agelaius phoeniceus*
Birds	Ring-necked Pheasant	*Phasianus colchicus*
Birds	Sandhill Crane	*Grus canadensis*
Birds	Song Sparrow	*Melospiza melodia*
Birds	Trumpeter Swan	*Cygnus buccinator*
Birds	Yellow Warbler	*Dendroica petechia*
Herps	Gophersnake	*Pituophis catenifer*
Herps	Western Hog-nosed Snake	*Heterodon nasicus*
Inverts	Leonard's Skipper	*Hesperia leonardus leonardus*

Table 8. Species encountered at study site 6 during project period. Target species are highlighted in gray.

Species Group	Common Name	Scientific Name
Mammals	Plains Pocket Mouse	*Perognathus flavescens*
Mammals	White-footed Mouse	*Peromyscus leucopus*
Birds	American Crow	*Corvus brachyrhynchos*
Birds	American Goldfinch	*Carduelis tristis*
Birds	American Robin	*Turdus migratorius*
Birds	Blue Jay	*Cyanocitta cristata*
Birds	Brown-headed Cowbird	*Molothrus ater*
Birds	Cedar Waxwing	*Bombycilla cedrorum*
Birds	Chipping Sparrow	*Spizella passerina*
Birds	Downy Woodpecker	*Picoides pubescens*
Birds	Eastern Bluebird	*Sialia sialis*
Birds	Eastern Towhee	*Pipilo erythrophthalmus*
Birds	House Wren	*Troglodytes aedon*
Birds	Lark Sparrow	*Chondestes grammacus*
Birds	Mourning Dove	*Zenaida macroura*
Birds	Northern Cardinal	*Cardinalis cardinalis*
Birds	Ovenbird	*Seiurus aurocapilla*
Birds	Pileated Woodpecker	*Dryocopus pileatus*
Birds	Rose-breasted Grosbeak	*Sitta canadensis*
Birds	Whip-poor-will	*Caprimulgus vociferus*
Herps	Blanding's Turtle	*Emydoidea blandingii*
Herps	Western Hog-nosed Snake	*Heterodon nasicus*
Inverts	Big Sand Tiger Beetle	*Cicindela formosa*

Table 9. Species encountered at study site 7 during project period. Target species are highlighted in gray.

Species Group	Common Name	Scientific Name
Mammals	Plains Pocket Mouse	*Perognathus flavescens*
Mammals	White-footed Mouse	*Peromyscus leucopus*
Birds	American Crow	*Corvus brachyrhynchos*
Birds	American Goldfinch	*Carduelis tristis*
Birds	American Robin	*Turdus migratorius*
Birds	Black-capped Chickadee	*Poecile atricapillus*
Birds	Blue Jay	*Cyanocitta cristata*
Birds	Brown Thrasher	*Toxostoma rufum*
Birds	Brown-headed Cowbird	*Molothrus ater*
Birds	Chipping Sparrow	*Spizella passerina*
Birds	Downy Woodpecker	*Picoides pubescens*
Birds	Eastern Towhee	*Pipilo erythrophthalmus*
Birds	Eastern Wood Pewee	*Contopus virens*
Birds	Field Sparrow	*Spizella pusilla*
Birds	Hairy Woodpecker	*Picoides villosus*
Birds	Indigo Bunting	*Passerina cyanea*
Birds	Lark Sparrow	*Chondestes grammacus*
Birds	Northern Cardinal	*Cardinalis cardinalis*
Birds	Northern Flicker	*Colaptes auratus*
Birds	Rose-breasted Grosbeak	*Sitta canadensis*
Birds	Sandhill Crane	*Grus canadensis*
Birds	Whip-poor-will	*Caprimulgus vociferus*
Herps	Gophersnake	*Pituophis catenifer*
Herps	Western Hog-nosed Snake	*Heterodon nasicus*

Table 10. Species encountered at study site 8 during project period. Target species are highlighted in gray.

Species Group	Common Name	Scientific Name
Mammals	White-footed Mouse	*Peromyscus leucopus*
Birds	American Crow	*Corvus brachyrhynchos*
Birds	American Goldfinch	*Carduelis tristis*
Birds	Black-and-White Warbler	*Mniotilta varia*
Birds	Black-capped Chickadee	*Poecile atricapillus*
Birds	Blue Jay	*Cyanocitta cristata*
Birds	Brown-headed Cowbird	*Molothrus ater*
Birds	Cedar Waxwing	*Bombycilla cedrorum*
Birds	Chipping Sparrow	*Spizella passerina*
Birds	Downy Woodpecker	*Picoides pubescens*
Birds	Eastern Towhee	*Pipilo erythrophthalmus*
Birds	Eastern Wood Pewee	*Contopus virens*
Birds	Field Sparrow	*Spizella pusilla*
Birds	Indigo Bunting	*Passerina cyanea*
Birds	Mourning Dove	*Zenaida macroura*
Birds	Northern Flicker	*Colaptes auratus*
Birds	Ovenbird	*Seiurus aurocapilla*
Birds	Pileated Woodpecker	*Dryocopus pileatus*
Birds	Red-breasted Nuthatch	*Sitta canadensis*
Birds	Red-eyed Vireo	*Vireo olivaceus*
Birds	Rose-breasted Grosbeak	*Sitta canadensis*
Birds	Scarlet Tanager	*Piranga olivacea*
Birds	Whip-poor-will	*Caprimulgus vociferus*
Herps	Gophersnake	*Pituophis catenifer*
Inverts	Leonard's Skipper	*Hesperia leonardus leonardus*

Table 11. Species encountered at study site 9 during project period. Target species are highlighted in gray.

Species Group	Common Name	Scientific Name
Mammals	Plains Pocket Mouse	*Perognathus flavescens*
Mammals	Prairie Deer Mouse	*Peromyscus maniculatus bairdii*
Mammals	White-footed Mouse	*Peromyscus leucopus*
Birds	American Crow	*Corvus brachyrhynchos*
Birds	American Goldfinch	*Carduelis tristis*
Birds	Baltimore Oriole	*Icterus galbula*
Birds	Blue Jay	*Cyanocitta cristata*
Birds	Brown Thrasher	*Toxostoma rufum*
Birds	Cedar Waxwing	*Bombycilla cedrorum*
Birds	Common Loon	*Gavia immer*
Birds	Common Yellowthroat	*Geothlypis trichas*
Birds	Eastern Towhee	*Pipilo erythrophthalmus*
Birds	Eastern Wood Pewee	*Contopus virens*
Birds	Field Sparrow	*Spizella pusilla*
Birds	Golden-winged Warbler	*Vermivora chrysoptera*
Birds	Grasshopper Sparrow	*Ammodramus savannarum*
Birds	Gray Catbird	*Dumetella carolinensis*
Birds	Great Crested Flycatcher	*Myiarchus crinitus*
Birds	Indigo Bunting	*Passerina cyanea*
Birds	Killdeer	*Charadrius vociferus*
Birds	Lark Sparrow	*Chondestes grammacus*
Birds	Mourning Dove	*Zenaida macroura*
Birds	Northern Harrier	*Circus cyaneus*
Birds	Red-eyed Vireo	*Vireo olivaceus*
Birds	Red-winged Blackbird	*Agelaius phoeniceus*
Birds	Ring-necked Pheasant	*Phasianus colchicus*
Birds	Sandhill Crane	*Grus canadensis*
Birds	Scarlet Tanager	*Piranga olivacea*
Birds	Song Sparrow	*Melospiza melodia*
Birds	Trumpeter Swan	*Cygnus buccinator*
Birds	Veery	*Catharus fuscescens*
Birds	Warbling Vireo	*Vireo gilvus*
Birds	Whip-poor-will	*Caprimulgus vociferus*
Birds	White-breasted Nuthatch	*Sitta carolinensis*
Birds	Yellow Warbler	*Dendroica petechia*
Birds	Yellow-throated Vireo	*Vireo flavifrons*
Herps	Blue-spotted Salamander	*Ambystoma laterale*
Inverts	A Jumping Spider	*Metaphedippus arizonensis*
Inverts	Big Sand Tiger Beetle	*Cicindela formosa*
Inverts	Leonard's Skipper	*Hesperia leonardus leonardus*

Table 12. Species encountered at study site 10 during project period. Target species are highlighted in gray.

Species Group	Common Name	Scientific Name
Mammals	Cinereus Shrew	*Sorex cinereus*
Mammals	Meadow Vole	*Microtus pennsylvanicus*
Mammals	Northern Short-tailed Shrew	*Blarina brevicauda*
Mammals	White-footed Mouse	*Peromyscus leucopus*
Birds	American Crow	*Corvus brachyrhynchos*
Birds	American Goldfinch	*Carduelis tristis*
Birds	American Redstart	*Setophaga ruticilla*
Birds	Bald Eagle	*Haliaeetus leucocephalus*
Birds	Baltimore Oriole	*Icterus galbula*
Birds	Black-capped Chickadee	*Poecile atricapillus*
Birds	Blue Jay	*Cyanocitta cristata*
Birds	Blue-winged Warbler	*Vermivora pinus*
Birds	Brown-headed Cowbird	*Molothrus ater*
Birds	Cedar Waxwing	*Bombycilla cedrorum*
Birds	Chipping Sparrow	*Spizella passerina*
Birds	Common Yellowthroat	*Geothlypis trichas*
Birds	Downy Woodpecker	*Picoides pubescens*
Birds	Eastern Bluebird	*Sialia sialis*
Birds	Eastern Kingbird	*Tyrannus tyrannus*
Birds	Eastern Phoebe	*Sayornis phoebe*
Birds	Eastern Towhee	*Pipilo erythrophthalmus*
Birds	Eastern Wood Pewee	*Contopus virens*
Birds	Field Sparrow	*Spizella pusilla*
Birds	Grasshopper Sparrow	*Ammodramus savannarum*
Birds	Great Crested Flycatcher	*Myiarchus crinitus*
Birds	Hairy Woodpecker	*Picoides villosus*
Birds	Indigo Bunting	*Passerina cyanea*
Birds	Lark Sparrow	*Chondestes grammacus*
Birds	Mallard	*Anas platyrhynchos*
Birds	Northern Cardinal	*Cardinalis cardinalis*
Birds	Northern Flicker	*Colaptes auratus*
Birds	Red-eyed Vireo	*Vireo olivaceus*
Birds	Red-tailed Hawk	*Buteo jamaicensis*
Birds	Red-winged Blackbird	*Agelaius phoeniceus*
Birds	Ring-necked Pheasant	*Phasianus colchicus*
Birds	Sandhill Crane	*Grus canadensis*
Birds	Song Sparrow	*Melospiza melodia*
Birds	Trumpeter Swan	*Cygnus buccinator*
Birds	Vesper Sparrow	*Pooecetes gramineus*
Birds	Yellow-throated Vireo	*Vireo flavifrons*
Herps	Gophersnake	*Pituophis catenifer*
Inverts	Big Sand Tiger Beetle	*Cicindela formosa*
Inverts	Eastern Tailed-Blue Butterfly	*Everes comyntas*
Inverts	Variegated Fritillary	*Euptoieta claudia*

Table 13. Species encountered at study site 11 during project period. Target species are highlighted in gray.

Species Group	Common Name	Scientific Name
Mammals	Meadow Vole	*Microtus pennsylvanicus*
Mammals	Northern Short-tailed Shrew	*Blarina brevicauda*
Mammals	Plains Pocket Mouse	*Perognathus flavescens*
Mammals	White-footed Mouse	*Peromyscus leucopus*
Birds	American Crow	*Corvus brachyrhynchos*
Birds	American Goldfinch	*Carduelis tristis*
Birds	American Kestrel	*Falco sparverius*
Birds	American Robin	*Turdus migratorius*
Birds	Black-and-White Warbler	*Mniotilta varia*
Birds	Black-capped Chickadee	*Poecile atricapillus*
Birds	Blue Jay	*Cyanocitta cristata*
Birds	Blue-winged Warbler	*Vermivora pinus*
Birds	Brown Thrasher	*Toxostoma rufum*
Birds	Brown-headed Cowbird	*Molothrus ater*
Birds	Chipping Sparrow	*Spizella passerina*
Birds	Common Raven	*Corvus corax*
Birds	Common Yellowthroat	*Geothlypis trichas*
Birds	Eastern Towhee	*Pipilo erythrophthalmus*
Birds	Field Sparrow	*Spizella pusilla*
Birds	Golden-winged Warbler	*Vermivora chrysoptera*
Birds	Indigo Bunting	*Passerina cyanea*
Birds	Lark Sparrow	*Chondestes grammacus*
Birds	Mourning Dove	*Zenaida macroura*
Birds	Northern Flicker	*Colaptes auratus*
Birds	Pileated Woodpecker	*Dryocopus pileatus*
Birds	Red-tailed Hawk	*Buteo jamaicensis*
Birds	Sandhill Crane	*Grus canadensis*
Birds	Song Sparrow	*Melospiza melodia*
Birds	Trumpeter Swan	*Cygnus buccinator*
Birds	Whip-poor-will	*Caprimulgus vociferus*
Herps	Blanding's Turtle	*Emydoidea blandingii*
Herps	Gophersnake	*Pituophis catenifer*
Herps	Smooth Greensnake	*Opheodrys vernalis*
Herps	Western Hog-nosed Snake	*Heterodon nasicus*
Inverts	A Jumping Spider	*Metaphidippus arizonensis*

Table 14. Species encountered at study site 12 during project period. Target species are highlighted in gray.

Species Group	Common Name	Scientific Name
Mammals	Meadow Vole	*Microtus pennsylvanicus*
Mammals	White-footed Mouse	*Peromyscus leucopus*
Birds	American Crow	*Corvus brachyrhynchos*
Birds	American Goldfinch	*Carduelis tristis*
Birds	American Robin	*Turdus migratorius*
Birds	Black-capped Chickadee	*Poecile atricapillus*
Birds	Blue Jay	*Cyanocitta cristata*
Birds	Blue-winged Warbler	*Vermivora pinus*
Birds	Brown-headed Cowbird	*Molothrus ater*
Birds	Cedar Waxwing	*Bombycilla cedrorum*
Birds	Chipping Sparrow	*Spizella passerina*
Birds	Common Loon	*Gavia immer*
Birds	Common Yellowthroat	*Geothlypis trichas*
Birds	Eastern Towhee	*Pipilo erythrophthalmus*
Birds	Eastern Wood Pewee	*Contopus virens*
Birds	Hairy Woodpecker	*Picoides villosus*
Birds	House Wren	*Troglodytes aedon*
Birds	Lark Sparrow	*Chondestes grammacus*
Birds	Mourning Dove	*Zenaida macroura*
Birds	Northern Cardinal	*Cardinalis cardinalis*
Birds	Ovenbird	*Seiurus aurocapilla*
Birds	Red-eyed Vireo	*Vireo olivaceus*
Birds	Sandhill Crane	*Grus canadensis*
Birds	Whip-poor-will	*Caprimulgus vociferus*
Birds	White-breasted Nuthatch	*Sitta carolinensis*
Herps	Common Gartersnake	*Thamnophis sirtalis*
Herps	Gophersnake	*Pituophis catenifer*
Herps	Plains Gartersnake	*Thamnophis radix*
Herps	Smooth Greensnake	*Opheodrys vernalis*
Inverts	Long-dash Skipper	*Polites mystic*
Inverts	Northern Barrens Tiger Beetle	*Cicindela paturela paturela*

Table 15. Mean home range size estimates for snakes' tracked using harmonic radar tracking technology (HR) and traditional radio (VHF) tracking technology (VHF). Home range estimates generated using minimum convex polygons (MCP) and 95% kernel density estimators (95% KD). Also shown are estimated activity centers calculated using 50% kernel density estimators (50% KD). * denotes statistically significant difference between means (using Welch's T-test to account for unequal variance). [a] indicates statistical significance between MCP and 95% KD home range estimates for snakes tracked using VHF (using a paired T-test).

Method	n	MCP	95% KD	50% KD
HR	6	1.1729	3.639	0.9278
VHF	10	11.2187 *[a]	26.0748 *[a]	5.9003 *

Table 16. Presence and relative abundance of targeted plant species within each study site.

Site Number	Common Name	Scientific Name	Number of Plants	Density Range
1	Hairy grama	*Bouteloua hirsuta*	>500	0.02 to 10/m^2
1	Roundhead bush clover	*Lespedeza capitata*	>1150<1500	0.02 to 0.86/m^2
1	Blazing stars	*Liatris spp.*	116	0.02 to 0.66/m2
2	Hairy grama	*Bouteloua hirsuta*	13	N/A
2	Roundhead bush clover	*Lespedeza capitata*	>18,000<21,000	0.02 to 9.5/m^2
2	Large flowered penstemon	*Penstemon grandflorus*	1	N/A
3	Roundhead bush clover	*Lespedeza capitata*	>100,000 <150,000	0.06 to 12/m2
4	Roundhead bush clover	*Lespedeza capitata*	>1,600 <2,000	0.02 to 9.0/m2
4	Blazing stars	*Liatris spp.*	318	0.02 to 2.1/m2
5	Hairy grama	*Bouteloua hirsuta*	>1,500 <2,000	0.02 to 10.0/m2
5	Roundhead bush clover	*Lespedeza capitata*	18	N/A
5	Blazing stars	*Liatris spp.*	743	0.02 to 2.0/m2
5	Large flowered penstemon	*Penstemon grandflorus*	1	0.02 to 6.0/m2
7	Roundhead bush clover	*Lespedeza capitata*	310	0.02 to 1.2/m2
7	Blazing stars	*Liatris spp.*	14	0.02 to 0.40/m
8	Hairy grama	*Bouteloua hirsuta*	>400 <450	3.0 to 7.50/m2
8	Blazing stars	*Liatris spp.*	41	0.02 to 3.0/m2
8	Large flowered penstemon	*Penstemon grandflorus*	2	N/A
9	Roundhead bush clover	*Lespedeza capitata*	>33,000 <35,000	0.02 to 9.0/m2
9	Blazing stars	*Liatris spp.*	129	0.02 to 4.0/m2
9	Large flowered penstemon	*Penstemon grandflorus*	214	0.02 to 0.70/m2
10	Roundhead bush clover	*Lespedeza capitata*	>1,600 <1,700	0.08 to 2.88/m2
12	Roundhead bush clover	*Lespedeza capitata*	1	N/A
12	Blazing stars	*Liatris spp.*	2	N/A
12	Large flowered penstemon	*Penstemon grandflorus*	3	N/A

Table 17. Relevès completed in 2011 at study sites.

Site Number	Relevé Number	Native Plant Community	Quality Rank	Date Completed
Site 1	9794	Prairie	B	25-Jul-11
Site 2	9793	Prairie	C	27-Jul-11
Site 3	9792	Prairie	BC	27-Jul-11
Site 4	9791	Prairie	B	27-Jul-11
Site 5	9790	Prairie	BC	26-Jul-11
Site 6	9789	Prairie	C	28-Jul-11
Site 7	9788	Prairie	C	28-Jul-11
Site 8	9787	Prairie	B	28-Jul-11
Site 9	9786	Prairie	BC	28-Jul-11
Site 10	9785	Prairie	C	27-Jul-11
Site 11	9784	Prairie	C	28-Jul-11
Site 12	9783	None (grassland)	none	28-Jul-11

Table 18. Comparison of home range size estimates for snakes tracked using VHF in Sand Dunes State Forest (SDSF) and Sherburne National Wildlife Refuge (SNWR).Both minimum convex polygon (MCP) and 95% kernel density estimates (95% KD) are shown. Also shown are activity center size estimates between SDSF and SNWR using 50% kernel density estimator (50% KD). [b] denotes non-statistically significant but biological important decreases in mean home range size estimates for snakes tracked in SNWR ($p = 0.12$; using Welch's T-test to account for unequal variance).

Site	n	MCP	95% KD	50% KD
SDSF	2	19.8075	46.7155	9.9674
SNWR	8	9.0716 [b]	20.9147 [b]	4.8836

Table 19. Relevé species richness and quality and number of animal species (including target and SGCN species) displayed in the order of tier ranks. Also included are the mean number of total native plant species per relevé plot and the mean number of several native and non-native plant species of various groups per relevé plot. SNWR = Sherburne National Wildlife Refuge, SDSF = Sand Dunes State Forest, Uncas Dunes = Uncas Dunes Scientific and Natural Area. Field data for this table available upon request.

Site Number	Tier Rank	Managed Area	Releve Number	Native Plant Community	Quality Rank of Releve	Native Woody & Climber Species	Non-native Woody & Climber Species	Native Forbs Species	Non-native forbs Species	Native Gram-inoid Species	Non-native Gram-inoid Species	Total Native Plant Species	# Target SGCN Species	Total # SGCN Species	Total # of Animal Species Recorded
Site 1	I	SNWR	9794	Prairie	B	2	0	30	6	9	1	**41**	**7**	**12**	**47**
Site 4	I	SNWR	9791	Prairie	B	1	0	21	1	7	1	**28**	**5**	**14**	**38**
Site 9	I	SNWR	9786	Prairie	BC	1	0	19	2	7	1	**27**	**5**	**13**	**40**
Site 2	I	SNWR	9793	Prairie	C	1	0	16	1	8	1	**25**	**4**	**13**	**45**
Site 3	II	SNWR	9792	Prairie	BC	0	0	17	1	6	1	**23**	**4**	**11**	**38**
Site 5	II	SNWR	9790	Prairie	BC	0	0	12	2	10	1	**22**	**3**	**9**	**33**
Site 7	II	SDSF	9788	Prairie	C	1	2	14	2	6	2	**22**	**3**	**8**	**24**
Site 11	II	SDSF	9784	Prairie	C	0	1	12	5	5	1	**17**	**4**	**11**	**35**
Site 8	III	SDSF	9787	Prairie	B	3	1	14	2	7	0	**24**	**2**	**7**	**25**
Site 6	III	SDSF	9789	Prairie	C	0	2	16	4	5	2	**21**	**3**	**6**	**23**
Site 10	III	SNWR	9785	Prairie	C	0	0	10	4	9	4	**19**	**1**	**7**	**44**
Site 12	III	Uncas Dunes	9783	(old field)	None	3	3	4	4	1	4	**8**	**2**	**7**	**31**
Mean						1	0.75	15.42	2.83	6.42	1.83	23.08			

Table 20. Relevé species richness and quality of several relevé plots in Savanna and Woodland across 11 managed areas within the Anoka Sand Plain subsection. Also included are the mean number of total native plant species per relevé plot and the mean number of several native and non-native plant species of various groups per relevé plot. Field data for this table available upon request.

Releve Location - Managed Area	Releve Number	Native Plant Community	Rank	Native Woody & climber Species	Non-native woody & climber species	Native Forb species	Non-native forb species	Native Graminoid species	Non-native graminoid species	Total # Native Plant Species
Cedar Creek	9883	Savanna	B	14	0	33	0	12	1	**59**
Sand Dunes SF South	9880	Savanna	BC	11	0	31	1	12	1	**54**
Uncas Dunes South	9876	Savanna	B	11	0	21	1	19	1	**51**
Bunker Hills Park	9890	Savanna	B	13	1	21	1	16	1	**50**
Wild River SP	9877	Savanna	BC	14	0	25	0	10	1	**49**
Rice Lake Savanna	9885	Savanna	CD	12	3	24	1	13	3	**49**
Sherburne NWR	9878	Savanna	B	11	0	23	0	14	1	**48**
Helen Allison	9882	Savanna	B	9	0	24	0	13	1	**46**
Oak Savanna Park	9887	Savanna	C	10	1	18	0	10	3	**38**
Carlos Avery	9889	Savanna	BC	9	1	13	0	13	2	**35**
Uncas Dunes North	9875	Savanna	B	7	0	17	1	10	1	**34**
Sherburne NWR	9879	Woodland	B	18	0	30	0	10	1	**58**
Oak Savanna Park	9888	Woodland	C	18	1	4	4	4	1	**45**
Cedar Creek	9884	Woodland	AB	17	1	23	2	4	0	**44**
Rice Lake Savanna	9886	Woodland	BC	14	1	16	0	4	1	**34**
Sand Dunes SF South	9881	Woodland	C	20	2	8	0	2	1	**30**
Mean				13	0.6875	21.8	0.6875	10.375	1.25	**45.33**

Appendix I – Western Hog-nosed Snake Home Range Estimation Maps

[redacted]

Map 1. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for adult male individual #D378 at study site 1. MCP home range estimate = 0.74 ha, 95% KD home range estimate = 5.2 ha, 50% KD activity center estimate = 1.4 ha.

Map 2. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for adult male individual #.119 at study site 1. MCP home range estimate = 3.91 ha, 95% KD home range estimate = 10.19 ha, 50% KD activity center estimate = 2.52 ha.

[redacted]

Map 3. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for adult male individual #.019 at study site 2. MCP home range estimate = 6.28 ha, 95% KD home range estimate = 12.40 ha, 50% KD activity center estimate = 2.54 ha.

Map 4. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for adult female individual #.057(CFF6) at study site 2. MCP home range estimate = 9.56 ha, 95% KD home range estimate = 26.84 ha, 50% KD activity center estimate = 5.38 ha.

Map 5. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for juvenile female individual #C6CE at study site 3. MCP home range estimate = .25 ha, 95% KD home range estimate = 3.27 ha, 50% KD activity center estimate = .93 ha.

[redacted]

Map 6. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for adult female individual #.108 at study site 3. MCP home range estimate = 10.44 ha, 95% KD home range estimate = 16.38 ha, 50% KD activity center estimate = 3.16 ha.

Map 7. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for adult female individual #.140(3276) at study site 3. MCP home range estimate = 5.52 ha, 95% KD home range estimate = 17.22 ha, 50% KD activity center estimate = 4.10 ha.

Map 8. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for adult male individual #F986 at study site 4. MCP home range estimate = 1.67 ha, 95% KD home range estimate = 5.97 ha, 50% KD activity center estimate = 1.56 ha.

Map 9. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for adult male individual #.044 at study site 4. MCP home range estimate = 5.55 ha, 95% KD home range estimate = 6.05 ha, 50% KD activity center estimate = 1.39 ha.

Map 10. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for adult female individual #.132 at study site 4. MCP home range estimate = 11.44 ha, 95% KD home range estimate = 24.75 ha, 50% KD activity center estimate = 6.08 ha.

[redacted]

Map 11. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for adult male individual #.032 at study site 4. MCP home range estimate = 19.86 ha, 95% KD home range estimate = 53.48 ha, 50% KD activity center estimate = 13.90 ha.

[redacted]

Map 12. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for adult female individual #FD00 at study site 11. MCP home range estimate = 0.22 ha, 95% KD home range estimate = 0.82 ha, 50% KD activity center estimate = 0.24 ha.

Map 13. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for adult female individual #EF4E at study site 11. MCP home range estimate = 3.68 ha, 95% KD home range estimate = 3.51 ha, 50% KD activity center estimate = 0.61 ha.

[redacted]

Map 14. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for adult female individual #F838 at study site 11. MCP home range estimate = 0.47 ha, 95% KD home range estimate = 3.06 ha, 50% KD activity center estimate = 0.84 ha.

Map 15. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for adult male individual #.069 at study site 11. MCP home range estimate = 33.29 ha, 95% KD home range estimate = 72.08 ha, 50% KD activity center estimate = 15.57 ha.

Map 16. Map showing minimum convex polygon (MCP) home range size estimate, 95% kernel density home range estimate (95% KD) and 50% kernel density estimated activity centers (50% KD) for adult male individual #.007 at study site 11. MCP home range estimate = 7.33 ha, 95% KD home range estimate = 21.35 ha, 50% KD activity center estimate = 4.36 ha.

Appendix II.
Minnesota Natural Heritage Program 4.2.0
Oak Woodland – Brushland
DRAFT EO Ranking Guidelines

1) minimum-size standard:
! 20 acres if present in a mosaic with prairies, savannas, and oak forests.
! 30 acres for isolated areas of good quality woodland.
! 40 acres for isolated areas of poor quality woodland.
! 3 acres for bluffland occurrences where rugged terrain, thin soils, and xeric aspect maintain the community (i.e., occurrences will not readily succeed to forest without management).

2) how are boundaries determined?:
! separation of woodland - brushland from adjacent forest and savanna communities may be difficult, particularly where there are not strong edaphic or other factors that determine the extent of the community.
Separation of woodland - brushland from adjacent forest or savanna communities is not always possible solely on the basis of percent cover. In general, however, the canopy cover is between 10-70% of the total area, with shrub-layer cover greater than 30%.

3) minimum condition-standard:
! has canopy dominated by *Quercus macrocarpa*, *Q. velutina*, *Q. ellipsoidalis*, *Q. alba*, or *Q. rubra*.
! has canopy cover between 30-70%, with trees of uniform height and less than 25 meters tall (mostly 15-25m).
! trees are either grouped together in groves or are uniformly distributed throughout community at a distance such that branches of adjacent trees do not intermingle.
! has shrub layer with > 30% cover and composed mainly of native shrubs (e.g., *Corylus americana*, *Cornus foemina*, *Viburnum rafinesquianum*, etc.).
! has open-grown trees with broad-spreading crowns or with crooked, distorted trunks because of loss of limbs caused by shading as tree densities increase. Crown height and crown spread ratios of individual trees are mostly between 1:1 to 2:1.
! has indistinct or irregular subcanopy.
! herb flora is a mixture of prairie and forest species and contains native species that generally decrease in abundance during grazing. (Prairie species are spotty to absent in the groundlayer on the Anoka sandplain and in northwestern Minnesota, with the groundlayer composed predominantly of plants tolerant of shade, such as *Parthenocissus* sp., *Carex pensylvanica*, and *Aralia nudicaulis*).

4) what is an A-rank EO?:
! at least half of the canopy is dominated by open-grown trees.
! lacks a subcanopy.
! has shrub layer with few individuals of thorny or otherwise unpalatable weedy species (e.g., *Ribes missouriensis*, *Zanthoxylum americanum*) or of forest species (e.g., *Cornus alternifolia*).
! typically has canopy gaps throughout site. Prairie herbs are present in canopy gaps, while shrubs or shadetolerant herbs are prevalent beneath tree groves.
! weedy Eurasian grasses such as *Poa pratensis* or *Agrostis stolonifera* are sparse or nearly absent.
! has not been heavily grazed, as evidenced by the species diversity within the community or in adjacent habitats (such as wetland rims).

! historical evidence (aerial photos, historic documents, etc.) suggests the area has been dominated by shrubs for long periods, even if not at the exact same location.

5) what is a B-rank EO?:
! has evidence of grazing, logging, etc., but these disturbances are minimal and recovery is likely over time. Indicators of past disturbance include human-made structures (trails, fences, foundations, wells, dumps, boulder piles); dense patches of clonal shrubs such as *Zanthoxylum*, *Rubus*, *Ribes*, etc.; an abundance of *Rhamnus* spp. and of grazing-increaser species; and a high frequency of multi-stemmed trees, stumps, or cow paths.
! weedy Eurasian grasses such as *Poa pratensis* or *Agrostis stolonifera* are common but not dominant. Native species that tend to increase during grazing are patchy or abundant in some areas. Most of the prairie vegetation is diverse, although scattered patches of low-diversity prairie may be present.
! has stem count ratio of open-grown to forest-grown trees nearly equal to or slightly less than one (yet community does not represent a true forest).
! subcanopy present but not well-defined. A few individuals of successional species (e.g., *Acer*, *Ostrya*, *Fraxinus*, *Carya ovata*) may be present in the subcanopy.
! has substantial numbers of weedy shrubs (e.g., *Ribes missouriensis*, *Zanthoxylum americanum*, *Lonicera tatarica*) but these do not dominate the shrub layer.

6) what is a C-rank EO?:
! site has been extensively grazed.
! soil compaction and livestock trails are obvious but not extensive.
! has few shrub species; most are thorny, unpalatable species that increase during grazing, although these form less than 50% cover.
! weedy herbs are common (but not dominant).
! many of the above-mentioned disturbance indicators are present.
! has ratio of open-grown to forest-grown trees of less than one, indicating succession to forest. Canopy cover is close to 70% and canopy may contain trees of shade-tolerant species such as *Carya ovata* and *Prunus serotina*, although overall the community does not fit the criteria of a forest.
! subcanopy is evident but not always distinct.

7) what is a D-rank EO?:
! is highly disturbed (has many disturbance indicators) and unrestorable.
! shrub layer is entirely dominated by thorny or unpalatable species (*Ribes missouriensis*, *Zanthoxylum americanum*, *Lonicera tatarica*) as a result of overgrazing.
! soil is severely compacted or eroded; many animal trails are present.
! groundlayer has low species diversity, being composed mainly of just two or three native species, or is predominantly of Eurasian grasses.
! in structure, community has basically succeeded to forest (e.g., ratio of open-grown to forest-grown trees is much less than one, canopy cover is greater than 70%, trees vary in height, and subcanopy is distinct).

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completed by: Scott Zager **date:** 4 May 1994
revised: 21 December 1994
7 February 1995
Notes:
1. The community/communities addressed in these guidelines follow the classification in:
Minnesota's Native Vegetation: A Key to Natural Communities, Version 1.5. 1993. Minnesota Department of Natural Resources Natural Heritage Program - Biological Report No. 20. 111 pp.
Please note that the classification described in the aforementioned document is currently undergoing revision, and certain community definitions may be changed in this revision process.

2. These guidelines are works-in-progress of the DNR's Minnesota County Biological Survey Program, and are, as such, at varying stages of completeness. We welcome any comments on these guidelines. Please send comments to: Data Manager, Minnesota DNR Natural Heritage and Nongame Research Program, 500 Lafayette Rd., Box 25, St. Paul, MN 55155 -OR- "Attn: Natural Heritage Program Data Manager" at: ecoservices@ dnr.state.mn.us.

Prescribed Fire Use and Important Management Considerations for Amphibians and Reptiles within the Midwest[1]

[1]Questions or comments contact:
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Chair Midwest PARC Fire and Herps Task Force
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It is well known that fire has historically played an important role in creating and maintaining ecosystems in the Midwest. In landscapes where fire has been suppressed or where invasive and exotic plant species have taken hold, prescribed fire is a useful tool for restoring native plant communities. This management technique can be valuable for increasing suitable habitat for some herpetofauna. However, there is a growing body of evidence that it may also be damaging to resident populations of reptiles and amphibians. When planning prescribed fires, habitat managers should consider the needs of all parts of existing floral and faunal communities. Maintenance of native animal populations, particularly vulnerable, rare or threatened species, deserve as much attention as the manipulation of plant communities toward a pre-determined goal. To assist land managers concerned about the impacts of fire on herpetofauna, the Midwest Partners in Amphibian and Reptile Conservation (PARC) provide the following recommendations to promote effective use of prescribed fire in ecosystem restoration.

It is important to know the suite of amphibian and reptile species that occur within your region and to conduct baseline inventories to determine the presence of species within areas proposed for management with prescribed fire. Although seasonal activity varies greatly depending on location and species, herpetofauna within the Midwest are generally inactive in the winter and underground or underwater, and so are less vulnerable to the impacts of fire. This offers a window of opportunity for burning. However, care must be taken to consider species assemblages that are present in a particular habitat prior to conducting burns. Burns around wetlands may interfere with salamander breeding migrations by removing the detritus upon which they rely for cover. Winter fires can also expose hibernating frogs and terrestrial salamanders using the detritus and duff for cover, insulation, and moisture retention. Early spring burns in forests may harm Eastern Box Turtles emerging from hibernation, while burns later in spring and early summer in meadows and old fields during nesting may impact turtles laying eggs. Turtle and some snake populations can be particularly sensitive to burns because the length of time for individuals to become sexually mature means that the loss of only a few adults can dramatically affect population viability. Prior to burning (or the use of other high-impact management methods such as mowing) in known turtle habitats, managers should carefully consider whether the end result will benefit their population viability and whether the actions themselves can be modified or timed seasonally to eliminate mortality. Any management plan that threatens the local or large-scale destruction of native turtles or any other vulnerable native animal populations should be considered inadequate and be reassessed.

Management Recommendations

The following recommendations have been compiled based on review of scientific literature, ongoing field research, and discussion amongst experts in the field of herpetology and prescribed fire management. These recommendations are not arranged in any particular order of importance.

1. **Identify the herpetofaunal diversity of your site prior to large scale management.** Identify species diversity, population size and geographic extant, and evaluate potential impacts of several alternatives, including the "no action" alternative regarding habitat change due to invasive species or succession. This information can be obtained by reviewing Natural Heritage database for records of rare or sensitive species in the vicinity of the burn, contacting researchers or local agencies charged with conservation and management of herps in your area, or contracting qualified biologists with a strong background in amphibians and reptiles to conduct comprehensive inventories.
2. **Burning should be conducted during winter months when most herps are inactive.** Most Midwest herpetofauna are in winter refugia during this period. In most areas this would be from November 1 to March 1, but will vary based on location and latitude as well as fluctuations in annual precipitation and temperature conditions. Soil temperature inversions (i.e., when soil surface temperatures exceed deeper soil temperatures) may be used as an indicator of the onset of activity for many reptiles. However, because some salamander species emerge from hibernation very early, February burns may impact salamander migration. It is necessary to understand where populations of these species occur and plan accordingly.
3. **Burning after April 1 is discouraged.** However, harm may be minimized for many species if unusually cool (overcast, <10° C (50°F) conditions have persisted for many days. Management plans should allow for flexibility to respond to each year's conditions-planning should be more conservative during unusually warm years. Box turtles will emerge after soil temperatures (10 cm down, detritus excluded) exceed 5C for several days.

They will be exposed thereafter, even if temperatures are subsequently cold.

4. **Spring burns in close proximity to snake hibernacula should be conducted well before the active season or not at all.** Snakes are concentrated early in the active season before they disperse from hibernacula and are vulnerable at that time. If these areas can be avoided and other management techniques used this would be preferable. Fire breaks constructed around known hibernacula may protect the animals during the burn.
5. **The intensity and speed of the flames should be adjusted and controlled to accommodate the herpetofaunal species present in the habitat.** Backfires and headfires may vary in mortality due to the slow and more complete burn of a backfire, compared to quick-moving headfires that tend to leave patches of refugia. It is important to know the species you are potentially impacting and their response to fire survival prior to utilizing a particular burn method. Few amphibian and reptile species can "outrun" fires. A rate such as 10ft. per minute may allow those species which evade fire to have time to flee. However, faster fires will leave unharmed areas under logs and other cover objects, allowing species that tend to hide to remain safe. Some species, such as Box Turtles, will remain in place during a fire. They do not attempt to run or to take cover. Instead they will close themselves into their shells to wait out the flames. Often, burned individuals who are not killed outright become vulnerable to potentially life-threatening infections. Alternatives to fire should be considered in habitats where Box Turtles are present.
6. **Consider burn patch size in fragmented habitats.** As ecosystems become increasingly fragmented it is important to consider the life history traits of many amphibians and reptiles when adopting fire as a management tool. If it is desirable to burn an area that is isolated from nearby habitats, it will benefit herpetofaunal populations if the area is divided into smaller segments and each segment burned on a different day or in different years.
7. **Consider summer burn costs and benefits.** Mid- to late-summer burns can be an effective tool for land managers targeting exotic vegetation. Due to the presence of green vegetation (i.e. brome, Kentucky blue-grass), late-season burns are often patchier, slower, and cooler than early spring burns. It is important to note, however, that summer burns in uplands can be very intense. When possible, only small units should be burned and extra measures should be taken to provide buffers around known herp concentrations (such as nesting areas).
8. **Avoid burns that completely expose soil over extensive areas.** If burning during the active season, weather or site conditions that result in spotty burns will be preferred. Some of these conditions include high humidity, green vegetation, and low temperatures. This approach also provides refugia for herpetofauna. Alternatively, fires breaks should be

created around select snags, standing dead trees, and downed logs to provide places for animals to escape the heat and flames. In addition to providing cover, this practice can dramatically reduce mop-up time.

9. **Alternate burn periods among years.** This action may also provide some relief to vulnerable herp populations. In general, diversifying the burn units and burn periods may be beneficial to a variety of grassland species and come closer to mimicking the natural burn regime that historically occurred on the land.
10. **Wetland shorelines should only be burned when a management objective specifically requires it.** Detritus provides cover for salamanders and frogs (and their prey) as they migrate to and from wetlands to breed. Create burn perimeters around these areas of at least 50ft when possible.
11. **Do not use fire retardant chemicals around wetlands as these chemicals may harm amphibians and other wetland species.** Fire retardant chemicals have been used to create burn breaks including around wetlands. Because of the sensitivity of amphibian skin, these compounds could cause harm to these animals. Instead, use a leaf blowers or rakes to create the desired barrier.
12. **Consider structural needs of the species present.** Although some habitats are not botanically rich, many such places support rich and viable populations of herpetofauna and other animals. These species often associate with structure and functions (e.g., existing prey base) rather than botanical assemblages and can flourish in areas that are of low botanic quality. Consult local experts (see recommendation 1 for types of contact) prior to initiating intensive restoration efforts in such areas as these actions might have a greater deleterious affect on animal communities than no action at all.
13. **Fall burns should follow an approach that takes the above guidelines into consideration.** The month of October is analogous to late March early April, and therefore many herpetofaunal species may still periodically be on the ground surface and active. Thus, burning prior to November 1 is discouraged. If possible burn oak forests while cool, but prior to leaf fall. This will help provide cover and insulation for wildlife using the forest floor over winter.
14. **Avoid constructing brush piles, and when they are necessary, burn them immediately.** Snakes and other wildlife will take advantage of the presence of new habitat like brush piles, creating traps during burns. If piles are left out for more than a few weeks, they should be disassembled prior to the burn. Alternatively, allowing some of the older brush piles to remain with burn breaks around them will not only add additional habitat for wildlife, but will provide refugia during a fire.
15. **Repeated burns will have cumulative effects on population viability.** Populations of turtles and several species of snakes are sensitive

to even small increases in mortality, especially if losses occur regularly. While only a few individuals may be lost during a single burn, recurring losses of a few individuals can quickly deplete populations of long-lived, slowly maturing animals such as turtles and many snakes.

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Appendix IV

Draft wildlife road crossing sign designed gratis by Wildlife Research & Consulting Services, LLC.

RACCOONS AND TURTLE CONSERVATION

Raccoons, *Procyon lotor*, are a well-known predator of eggs, hatchlings, and adult turtles. Some populations of turtles experience complete nest failure for many successive years due to raccoon predation. The variability in annual reproductive output and time to reach to sexual maturity causes some Midwestern species to be more greatly impacted by raccoons than other species.

Throughout most of the Midwest data indicates that raccoon populations are at record highs. Several factors are contributing to these numbers, but human subsidies have a large impact. Subsidies are provided not only in the form of increased food availability, but also in the form of additional human supplied refuge. Human supplied food subsidies come in the form of agricultural byproducts, garbage, and intentional feeding.

With the increasing suburbanization of our natural areas, raccoons are getting unneeded and unprecedented human assistance. At the same time, as natural areas become developed turtle populations become fragmented. This fragmentation disrupts population connectedness and exacerbates the effects of elevated raccoon predation.

Although raccoon predation is not the only conservation issue facing our Midwestern turtles, it is an important and significant source of turtle mortality. It is the position of Midwest PARC that efforts should be made to control raccoon populations, especially around critical turtle habitat. Turtles in general are extremely long lived and may benefit from even periodic relief from this source of predation.

Discourage feeding of raccoons. Make efforts to eliminate sources of garbage that may be accessible to raccoons. Do not feed wildlife.

Check local wildlife regulation. Releasing, rehabilitating, and feeding may already be illegal in many states or municipalities. Where present these regulations need to be enforced.

Do not provide raccoons with refuge. Secure vacant buildings to eliminate resident raccoons. Repair areas within used structures to ensure raccoons don’t take up residents.

Open land to trapping. Most states allow for raccoon trapping. Developing a relationship with local trapper may be a viable solution. Care should always be taken to follow state trapping regulations.

Manage Raccoon populations. In some locations it may be most beneficial to initiate a raccoon control program, in accordance with local regulations. Raccoon control can easily be achieved by systematic trapping and elimination of captured raccoons. Raccoons should be humanely dispatched in accordance with the American Veterinary Medical Associations guidelines for euthanasia (http://www.avma.org/issues/animal_welfare/euthanasia.pdf). In the majority of studies, removal of raccoons has had a measurable impact on turtle populations. Whenever possible, raccoon management and turtle populations should be monitored in an effort to document your results.

Please see http://www.mwparc.org/products/raccoons/ (next section below) for a List of Relevant Literature

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