Final Report: Illinois Wildlife Preservation Grant Agreement # 13-013W

Project Title: Conservation Assessment of Smooth Green Snakes (*Opheodrys vernalis*) in DuPage and McHenry Counties

Allison Sacerdote-Velat, PhD.
Lincoln Park Zoological Society, Department of Conservation & Science
2001 N. Clark Street, Chicago, IL 60614
(312) 742-9788
asacerdote@lpzoo.org

OBJECTIVES

(1) Identify sites in McHenry and DuPage Counties with increased likelihood of *O. vernalis* occurrence using habitat suitability models in Arc GIS v. 10. GIS-based models of habitat suitability for *O. vernalis* used in this study were developed for the Lake County Forest Preserve District, but model parameters are readily applicable for the McHenry County Conservation District and the Forest Preserve District of DuPage County.

(2) Implement site occupancy surveys for *O. vernalis* in selected sites using coverboards, and visual encounter surveys. Occupancy models will be generated to examine *O. vernalis* presence in response to restoration management (e.g. burning) and habitat type. Each selected site will be surveyed at least five times between May 2013 and September 2013.

(3) Conduct baseline mark-recapture surveys and estimate population sizes in each site as recaptures allow.

(4) Assess the number of regional populations of *O. vernalis* across McHenry, DuPage, and Lake Counties, and provide a baseline estimate of population size in sites where *O. vernalis* is present as recaptures permit.

INTRODUCTION

This study expanded on existing survey efforts and population assessments for the grassland-dependent smooth green snakes (*Opheodrys vernalis*), identified as a Species in Greatest Need of Conservation in the Illinois Wildlife Action Plan. Lincoln Park Zoo and the Lake County Forest Preserve District formed a conservation partnership in 2010 focused on the assessment and recovery of *O. vernalis* within Lake County preserves. In 2013,the zoo's Urban Wildlife Institute expanded the *O. vernalis* conservation assessment from Lake County into preserve sites with suitable grassland habitat in neighboring McHenry and DuPage Counties. As part of the Chicago Wilderness conservation region, McHenry and DuPage counties offer opportunities for *O. vernalis* recovery through restored and remnant protected habitat approaching 25,000 acres in each county (50,000 acres total), and offer additional populations for local assessment and conservation management. This study fulfills objectives identified in

the Illinois Wildlife Action Plan, including informing knowledge gaps regarding a species whose population status and distribution is uncertain, identification of small and declining populations, and assessment of key habitat variables for conservation of an increasingly rare species.

Few monitoring efforts exist to provide data regarding population declines of *O. vernalis* in Illinois, and there is an additional need for regional assessment. The species has suffered range-wide declines and is designated as state threatened, endangered, or of special concern in Indiana, Iowa, Wyoming, North Carolina, Colorado, Montana, and Nebraska. Despite these designations, no recovery or management plans currently exist for *O. vernalis* (Redder *et al.* 2006). Fewer than 10 populations are thought to persist in Iowa (Christiansen and Bailey 1993, Cox *et al*. 2005) and the species is considered extirpated in Missouri (Levell 1997). Declines are attributed to loss of grasslands and increased use of insecticides (Smith 1961, Oldfield and Moriarty 1994).

In this study, repeated surveys of artificial cover objects and natural cover provided estimates of detection probability and conditional occupancy (the percent of the area occupied in a particular site given the detection probability) across the available grassland habitats, using an occupancy modeling framework. Occupancy modeling relies on repeated sampling of multiple sites to generate data regarding the probability of detection if a species is present in a site. It is particularly useful for assessing the distribution of rare and cryptic species in that is integrates the detection probability from repeated sampling into the estimate of the proportion of area occupied (Durso *et al*. 2011).

We used Program PRESENCE software (Hines 2006), to calculate detection probability based on detection histories from surveys and adjusts the naïve or raw estimate of the number of occupied patches by the likelihood of detection. This approach is especially useful for examining landscape-scale patterns of site occupancy with rare and cryptic species where detection is generally imperfect (Durso *et al*. 2011). Site-specific and landscape-scale habitat characteristics were examined in relation to *O. vernalis* detection histories. Site covariates, including factors such as the time since a habitat patch was last burned, may influence within-site habitat use, or site occupancy, on a local scale. With regard to restoration management, we examined if the time since a site was burned ("burn interval") affected site occupancy. Burn interval was selected because it is a commonly used restoration management technique in grassland habitats. However, if the timing of prescribed burns overlaps with the activity window for the species, it may result in direct mortality or loss of subpopulations within a site. Landscape-scale covariates such as the amount of development and agriculture surrounding a set of preserves may also influence patterns of occupancy related to the ability of snakes to recolonize a habitat following restoration, or the ability of gene flow to persist among neighboring sites.

METHODS

Expansion of *O. vernalis* survey efforts used habitat suitability models developed for Lake County during recovery planning as a starting point for survey site selection. Each county in the Chicago Wilderness region has secondary community classification layers available in ArcGIS. The secondary community classifications allow the identification of preferred habitats for *O. vernalis* within the county's preserves. The secondary community classifications and other habitat variables (e.g. distance to roads, proximity to rivers, etc.) were used to apply the habitat suitability models for each county. The highest-ranking sites were intensively surveyed for *O. vernalis*. Survey site selection was supplemented with historical records of *O. vernalis* presence provided by the Forest Preserve District of DuPage County and the McHenry County Conservation District.

Surveys involved the placement and monitoring of coverboard arrays and visual encounter surveys at random points within appropriate community types. Community types included tallgrass prairie, sedge meadow, savanna, open canopy wetland edge, and "cultural grass" or old field areas. Additional transects were placed near open canopy riparian habitat in prairie/savanna edge and along railroad embankments that are typically used as wildlife corridors for landscape scale movements between preserved lands.

To detect *O. vernalis*, we conducted visual encounter surveys consisting of random, meandering walks through appropriate habitat in which natural cover objects were carefully turned and replaced. A minimum of five visual encounter surveys were conducted in each site. At least two coverboard arrays were placed and surveyed at each site. Coverboard arrays consisted of 50-meter transect lines, each with five 2' x 2 ' x 1/4" plywood boards and two rubber mats, with 10 meters between each cover object (Figs. A1, A2 – Supplement). Similar cover objects have been successfully used for monitoring smooth green snakes in Lake County, detecting both sexes of snake, all age classes, and nests during 2010, 2011, and2012 surveys. Coverboard surveys at each site occurred at least 14 times during the active season (May-September, 2013). Drift fences were not constructed because no areas of particularly high *O. vernalis* densities were located other than in West Chicago Prairie, an Illinois Nature Preserve site adjacent to the Union Pacific Rail Yard in DuPage County. We surveyed a total of 10 sites in DuPage County with 185 coverboards on 30 transects, and 14 sites in McHenry County with 300 coverboards on 50 transects. Each site had between two and seven transects depending on the amount of available habitat (Tables 1, 2).

All snakes encountered during sampling were identified to species and sex, and mass, snout-vent length, tail length, and reproductive conditions were recorded. All captures received an individual mark by cauterizing ventral scales with a veterinary surgical cautery. This is a common technique for individually marking small-bodied snakes that are too small for PIT tags (Cox *et al*. 2005). Weather conditions and habitat type were recorded as sampling and site covariates.

Survey Sites

We surveyed a total of ten sites in DuPage County: West Chicago Prairie, Pratt's Wayne Forest Preserve/James 'Pate' Philip State Park, Swift Prairie, East Branch Preserve, Churchill Woods, Timber Ridge, Blackwell Preserve, Night Heron Marsh, and Waterfall Glen.

We surveyed a total of 14 sites in McHenry County: Alden Sedge Meadow, Barber Fen, Boger Fen, Fel-Pro RRR, Glacial Park, Goose Lake, Hebron Peatlands, Hickory Grove, Lake Elizabeth, Lake in the Hills Fen, Larsen Prairie, North Branch, Pioneer Fen, Pleasant Valley, and Chain O' Lakes State Park.

Site-based Estimates of Occupancy

Occupancy models in Program PRESENCE (Hines 2006) were used to estimate proportion of area occupied by *O. vernalis* in preserved grasslands across each county, and to examine their use of restored habitat and response to prescribed burn intervals (Redder *et al*. 2006). A total of 15 coverboard surveys at each transect were pooled by month to create five survey periods: May, June, July, August, and September. Occupancy (Psi) and detection probability (p) were estimated for each transect as the individual sampling unit, corresponding to habitat patches within sites. The site covariate of burn interval (or time since the site was last burned) and sampling covariates of average monthly temperature and average monthly precipitation were included in several candidate models. All covariates were standardized with a z-transformation prior to analysis in PRESENCE. Seventeen models were tested and were evaluated using AIC weights and maximum likelihood estimates (Table 3).

Landscape-scale Occupancy Factors

We examined the influence of landscape-scale habitat characteristics on *O. vernalis* occupancy using Arc GIS v. 10. Multi-ring buffers were created around each sampling transect at distances of 25m, 50m, 100m, 250 m, 500 m, and 1000 m. Illinois GAP Analysis land cover data were clipped to each buffer to determine the ratio of open canopy habitat to closed canopy habitat, the proportion of each buffer in agriculture, and the proportion of each buffer in developed land. Low, medium, and high intensity development were pooled into one development category. All landscape-scale covariates were standardized with a z-transformation prior to analysis. Seven candidate models (Table 4) were examined at the six spatial scales in PRESENCE.

RESULTS

Opheodrys vernalis Populations

A total of 480 coverboards were checked a total of 15 times each, producing a total of 7,200 individual board surveys. Boards were pooled by transect, producing 80 sampling units and collapsing the surveys into 1,120 coverboard array checks between May and September 2013. Coverboard checks were further pooled by month into 224 sampling occasions across sites. A total of 115 visual encounter surveys were conducted across 23 sites. Only two *O.vernalis* populations were documented in DuPage County (in West Chicago Prairie and Pratt's Wayne Woods: Figs. A7, A8 – Supplement), and only three populations were documented in McHenry County (in Fel-Pro RRR Preserve, Glacial Park, and Pleasant Valley Conservation Area: Figs. A9-A11 – Supplement). Total captures of *O.vernalis* were extremely low in all sites in DuPage and McHenry County. One additional observation of an individual *O. vernalis* was recorded by the site steward at Lake in the Hills Fen prior to sampling in April 2013 (Fig. A12 – Supplement). West Chicago Prairie in DuPage County produced the greatest number of captures with a total of seven *O. vernalis*. Across all surveys, a total of eleven smooth green snakes were encountered; eight in DuPage County and three in McHenry County (Table 5).

Site-Based Occupancy Estimates

Candidate models were ranked using AIC weights and the best fit model was identified as constant occupancy of sites throughout the survey year, with variable detection probability through time, and with burn interval (Table 6).

The naïve estimate of occupancy across all sites in all models was 0.1375, or that 14% of available habitat was occupied. However, the real estimate of proportion of area occupied by *O. vernalis*, adjusted for detection probability was 0.1802 ($\pm$ 0.05), or 18%, across McHenry and DuPage counties. Detection probability varied across surveys through time and increased with decreasing time since prescribed burns (Table 7). The greatest detection probabilities occurred between May and July.

Conditional occupancy (Psi, given the detection probability) was estimated for individual transects and then averaged to obtain the mean estimate of percent area occupied in grassland habitat for each site in McHenry (Figs. 1, 3) and DuPage Counties (Figs. 2, 4).

Landscape-Scale Factors

The best-fit occupancy models varied by scale examined in Program PRESENCE. At the smaller scales of 25m and 50m, the percentage of area in open canopy habitat and the percentage of developed area was a the major factor influencing *O. vernalis* occupancy (Table 8). At 100 m, the proportion of area in open canopy and area in agriculture most strongly influenced occupancy. At 250 m, open canopy area was still the strongest influence. At the larger scale of 500 m, the proportion of developed area had the strongest effect on occupancy. At 1000m, occupancy was most influenced by proportion of area in development and by area in agriculture (Table 8).

Total Captures and Species Richness

Total captures across snake species varied by site in each county. In McHenry County, Glacial Park produced the greatest number of snake captures overall, followed by Goose Lake, Fel-Pro RRR, Pleasant Valley Conservation Area, and Pioneer Fen. The remaining sites had very few captures of any snake species (Fig. 5). Species richness also varied by site. Glacial Park and Pleasant Valley had four snake species each, while the remaining sites each had only two or three species detected, typically with either brown snakes or red-bellied snakes dominating the captures (Fig. 5).

In DuPage County, the total captures across snake species were greatest at West Chicago Prairie and Pratt's Wayne Preserve. The remaining sites produced low numbers of captures across species (Fig. 6). Species richness varied by site; West Chicago Prairie, Pratt's Wayne, and Waterfall Glen each produced five species of snake, while the remaining sites each produced 0-3 species in very low numbers. Churchill Woods and Night Heron Marsh did not produce any snake captures.

In McHenry County, when captures by species were pooled across sites, the snake assemblage was dominated by common gartersnakes and DeKay's brownsnake, followed by red-bellied snakes. Fewer than 10 smooth greensnakes, eastern fox snakes, and plains gartersnakes were encountered during coverboard and visual encounter surveys (Fig. 7). In each of the three sites where *O. vernalis* was detected, only a single individual was encountered.

In DuPage County, when species captures were pooled across sites, the snake assemblage was also dominated by common gartersnakes and DeKay's brown snake, with fewer than 10 captures each of smooth greensnakes, eastern fox snakes, and plains gartersnakes. A total of eight smooth greensnakes were encountered. No red-bellied snakes were encountered in DuPage County sites, but a few incidental captures of northern watersnakes and one queen snake occurred during visual encounter surveys along Sawbuck Creek in Waterfall Glen (Fig. 8).

DISCUSSION

Through the use of intensive cover object surveys and visual encounter surveys in 23 sites across 80 transects in DuPage and McHenry County, only five populations of *Opheodrys vernalis* were

documented in the 2013 surveys. Captures were low in all sites, and recruitment was only documented at the West Chicago Prairie site in DuPage County, although two females captured at Glacial Park and Fel Pro in McHenry County appeared gravid. In DuPage County, all observations of *O. vernalis* by District personnel in the last ten years were restricted to West Chicago Prairie and Pratt's Wayne Preserve. These two sites were the only DuPage County preserves to produce *O. vernalis* during the 2013 survey efforts.

Although there is high-quality habitat available within the core area of West Chicago Prairie, the only three *O. vernalis* nests observed were located under an erosion control blanket at the periphery of the site, along the Union Pacific Rail Yard (Figs. A3-A7 – Supplement). While some evidence of hatching success was documented, hatching failure was also observed when, after several weeks without rain, three eggs desiccated just prior to hatching. Cover objects like erosion control blankets offer thermal refugia, but also act as sponges during dry periods and may therefore represent a reproductive sink for several species, including *O. vernalis*. In addition to documenting desiccated nests, one juvenile *O. vernalis*, three adult *T. sirtalis*, and two adult *S. dekayi* were found dead beneath the erosion blanket. Snakes may use the erosion blankets as thermal oases, but become trapped beneath them in heavy rain episodes. Additionally, erosion control blankets are often manufactured with a plastic mesh base which can cause entanglement of snakes as the organic components of the blanket erode (Kapfer and Paloski 2011). Further study is warranted to examine the frequency of use of this material by snakes, and the associated risks. Collection by hobbyists may pose an additional threat to snake populations at the West Chicago Prairie site. During this study, a monitored nest containing four eggs was removed from the site by an unknown party. Several people unaffiliated with any research or management agency were observed flipping cover to look for snakes along the rail yard edge of West Chicago Prairie in the vicinity of the missing nest. These incidents were reported to DuPage County law enforcement and biologists.

McHenry County Conservation District supplied past survey data from 1989-2010 for *O. vernalis* populations that included Alden Sedge Meadow, Lake Elizabeth, Glacial Park, Lake in the Hills Fen, and Pleasant Valley. Our 2013 surveys did not detect populations in Alden Sedge Meadow or Lake Elizabeth. There was a single observation of *O. vernalis* at Lake in the Hills Fen in early May, but no *O. vernalis* were documented during coverboard surveys at the site. The area of Alden Sedge Meadow that had produced captures in 1989 surveys has since become pervaded with Autumn Olive and Honeysuckle shrubs, and the *O. vernalis* distribution within the site may have shifted in response to the change in canopy cover. While Alden Sedge Meadow and Lake Elizabeth did not produce *O. vernalis* in 2013, a single capture at Fel-Pro RRR Preserve represents an additional population to monitor in the future.

The low detection probability of *O. vernalis* makes the species a challenging subject to monitor, as compared to other grassland snake species. As with many cryptic species, it is difficult to discern if non-detection is reflective of true absence (Durso *et al*. 2011). Other regional grassland snake surveys in Illinois produced similarly low capture numbers for the species in the past two decades (Mierzwa 1994, Cagle 2008). Cagle (2008) surveyed six grassland preserves in four counties in the Grand Prairie region of Illinois (Will, Grundy, Livingston, and Lee) with a total of 22 drift fences, which produced a total of only four *O. vernalis* captures between May and August, 2007. The four captures produced came from two drift fences in one survey site, Green River Wildlife Area, in Lee County. The low number of captures across sites regionally is a cause for concern regarding the extent of population decline. Given the challenge of low detection probability, coverboards and visual encounter surveys are the best

available methods for repeated sampling of multiple sites over time. The site-based estimates of occupancy for *O. vernalis* produced in this study demonstrate a strong pattern of variation in detection probability with time; based on survey results, sampling effort is best invested between May and July when mating occurs and when gravid females are more likely to use cover objects for thermoregulation.

Prescribed Burning

While it was expected that the time since prescribed burning would affect site occupancy, there was no effect of within season or recent (within 3 years) prescribed burning on site occupancy. However, given the low number of sites with *O. vernalis*, we are not yet able to fully discern the impact of prescribed burn management on the species. While burn interval may influence a snake's use of a habitat patch, the fire intensity, extent of the fire, timing of the fire (spring versus winter) and the presence of sufficient fire refugia in a site will all contribute to reptile use of burned habitat patches (PARC 2006). Certainly, incorporating a mosaic approach to prescribed burning (leaving some areas unburned) will allow snakes to escape to refugia if they are active during burning. As an example, West Chicago Prairie was partially burned within season and still produced the greatest number of *O. vernalis* captures. Despite the short interval between burning and the commencement of surveys (approximately two months), juvenile and adult *O. vernalis* were captured under boards within the burned area during May. This indicates that sufficient burn refugia were present nearby, which allowed survival and rapid recolonization of the burned patch. The higher density of *O. vernalis* along the shaded railroad yard at West Chicago Prairie may indicate that some snakes moved out to unburned areas and did not return to the core grassland habitat for nesting within the season. The Poverty Prairie section of Waterfall Glen was also burned within season and common gartersnakes (*Thamnophis sirtalis*) and Dekay's brown snakes (*Storeria dekayi*) were detected beneath boards in the burned patch by early June. Similarly, one transect at Lake Elizabeth was placed within a recently burned area adjacent to wet prairie and captures of *T. sirtalis* and *S. dekayi* occurred beneath coverboards by early June.

In contrast, Churchill Prairie in Churchill Woods Nature Preserve was burned in season, approximately two months before surveys commenced, and did not produce any snake captures. Lake in the Hills Fen was burned within season and no snake captures occurred beneath coverboards until mid-August, with captures of a single *T. sirtalis* and a single *S. dekayi*. One *O. vernalis* was observed moving through an unburned patch at Lake in the Hills Fen in early May, but the site produced no *O. vernalis* captures. In sites that produced few snake captures early in the season, it may be the case that the extent of the burn limited refugia and snakes had not yet colonized from surrounding areas. This was likely the case in a previously studied Lake County site, Berkeley Prairie. In 2009, Berkeley Prairie, a small 10 acre remnant prairie in Highland Park, consistently produced *O. vernalis* captures beneath two coverboards. The entire site was burned in November of 2009 and no *O. vernalis* were captured in the site between 2010 and 2012. In 2010, no species of snake were encountered in the site until late July, when captures included a single plains gartersnake (*Thamnophis radix*) and several gravid redbelly snakes (*Storeria occipitomaculata*). Based on the low number of detections in 2013, it was not possible to ascertain the effect of burn interval on site occupancy. In addition, we were unable to incorporate detailed data regarding the extent of each burn versus presence of refugia, as the only data currently available are general estimates of acreage burned and the direction of the fires. However, fire extent and presence of refugia are factors that will be examined in future studies as data permit.

For the site-specific occupancy estimates, detection probability increased slightly with shorter intervals between burning and surveys. As prescribed burning reduces the density of vegetation structure in grasslands, surveyors were more likely to find *O. vernalis* in areas that had been burned within 1-2 years of the survey. Similarly, detection probability decreases later in the active season, which may be related to regrowth of vegetation structure several months after a burn, general increase in vegetation height in late summer, and to changes in thermoregulatory behavior of female snakes after egg-laying is complete. Detection probability was greatest during the window of time when gravid *O. vernalis* are seeking thermal oases such as coverboards.

With regard to landscape-scale determinants of *O. vernalis* occupancy, there was variation in the influence of habitat factors at different scales. On the patch-level and site-level scale (25m, 50m, and 100m), *O. vernalis* occupancy was influenced by the proportion of open canopy habitat within the respective buffer zones around each sampling transect. At this smaller scale, open canopy habitat provides important areas for thermoregulation, especially for gravid female snakes, and provides a prey base of grazing arthropods that feed on prairie plants. At 250m, canopy openness was still influential in patterns of occupancy. However, for the larger landscape scale (500m and 1000m), proportion of area in development and in agriculture affected occupancy more than canopy openness. Developed areas and row crop agriculture are difficult for *O. vernalis* to cross through as they would be subject to greater predation, injury, and road mortality. It is important to examine the way surrounding land cover may shape patterns of patch occupancy, as such factors may explain patterns of persistence and recolonization despite habitat fragmentation and habitat restoration. While the vegetative community within a site may be restored to a high quality ecosystem, landscape-scale factors may determine which restoration sites support a target species in the future. Cagle (2008) found that *O. vernalis* were negatively associated with urban development within 10 km of survey sites. However, the survey counties for Cagle's 2007 study were in areas of greater agricultural cover, and less area in development, within smaller distances of the survey sites as compared to survey sites in DuPage or McHenry County.

Restoration Management Recommendations

The low number of captures of *O. vernalis* may indicate that there are several factors at play contributing to decline of regional populations. While the species is small-bodied and feeds on arthropods and may therefore be present in high densities in small habitat patches, restoration management planning should take the life history of the species into consideration.

Actions Needed:

1. *Continue to acquire preserve land with either suitable remnant grassland habitat or the potential for restoration to suitable habitat. Ideally, land incorporated into preserves in the region will have historically supported populations of O. vernalis.*
    a. This objective is continually being met by the DuPage and McHenry County Forest Preserve and Conservation Districts through land purchases. Restoration management is ongoing on most sites operated by the Forest Preserve District of DuPage County and the McHenry County Conservation District.

2. *Restoration management should include management for open-canopy to low-canopy cover conditions in a portion of the site such that portions of the site have between 25-75% canopy closure overall, and that areas exist with a maximum of 35% canopy cover.*
    a. This objective may be accomplished through removal/clearing of invasive exotic shrubs such as honeysuckle and buckthorn, and weedy native species with high potential for encroachment. While areas of shrubland should be maintained for birds, succession should be monitored to ensure that some open areas of approximately 1.5-2.0 ha (minimum) persist in each release site.
    b. Prescribed burns should be used to maintain open canopy conditions. However, burns should not encompass 100% of the suitable *O. vernalis* habitat such that if burns occur while snakes are active, there are refugia present to allow escape. A mosaic of adjacent burned and unburned patches is desirable as snakes can take refuge in unburned areas and then colonize burned areas later in the growing season (Setser and Kavitt 2003). Burn locations should be rotated across years to allow colonization of burned areas over time. Lack of refugia can increase snake susceptibility to avian predation events (Wilgers and Horne 2007).
    c. Prescribed burns in *O. vernalis* habitat should ideally occur in conditions < 50° F, prior to spring rains and thawing conditions. The optimal time window for prescribed burns in *O. vernalis* habitat is between November and late March, prior to the snakes' emergence in April and early May. Winter burns are preferable since the springtime temperatures in northern Illinois may result in early egress from brumation. If specific population locations are known, these areas should be provided with a buffer of 50-100 meters when burning. If known population sites must be burned for restoration, designated burn areas should provide significant refugia near the burn for snakes. If possible, burns should be planned in a mosaic fashion, rotating which areas are burned at a given time rather than encompassing the entirety of the core habitat at once. Additionally, for winter burns, care should be taken to protect some of the larger-diameter (< 7") downed logs that *O. vernalis* may use for shelter during brumation.
    d. Similarly, if brush piles are created during the course of clearing for restoration, they should either be immediately burned, or left in place if not burned within one season. Brush piles provide thermal oases and shelter for snakes, especially during burn season when other vegetative cover is reduced in the burn. If brush piles are left in place for over a year, they may become an ecological sink, attracting snakes, but causing mortality if they are suddenly burned after being left in place over many months.

3. *Maintenance of variability in habitat structure*
    a. Because *O. vernalis* use partially shaded areas and downed logs for nesting sites and occasionally for denning sites, grasslands should not be completely devoid of trees/canopy cover. If clearing shrubs or encroaching trees, occasional trees or brush may be left to provide diverse thermal environments (PARC 2006). When conducting prescribed burns, care should be taken to protect large downed logs and similar refugia.

4. *Mowing for restoration efforts should be done in a way that minimizes snake mortality.*

a. Mowing is often necessary to encourage establishment of native grassland species and to control invasive species. Snakes tend to bask along mowed edges of habitat when conditions are cool but sunny. This mowed edge habitat is typically avoided in hot temperatures. To minimize snake mortality, mowing should occur when it is overcast and the air temperature is <50° F, overcast and > 85° F, or during the driest and hottest part of the day. *Opheodrys vernalis* are often found basking on the margin of mowed grass/tallgrass between 8-11 A.M. for thermoregulation. Most often, the snakes using this margin are gravid females, so mower-relating mortality may directly impact recruitment. After 11 A.M., the snakes are typically foraging in the tallgrass habitat rather than using the mowed area. The exceptions are days when rain occurs in the morning and the afternoon is clear. To further reduce mower-related mortality, mower blades should be set a sufficient height to limit snake mortality. Setting the mower deck a minimum of 8-12", mowing in rows rather than in a circular pattern, and limiting disking to the dormant season for snakes is recommended (PARC 2006). In preserves with mowed grass trails (e.g. Glacial Park, Lake in the Hills Fen) special care should be taken to observe the appropriate times of day for mowing as snakes utilize overgrown paths for thermoregulation.

5. *Erosion control materials*
    a. Several studies have documented snake mortality resulting from entanglement in plastic erosion mesh netting used in restoration efforts for bank stabilization (Stuart et al. 2001, Barton and Kinkead 2005, Walley et al. 2005 a, b, Kapfer and Paloski 2011). In contrast, effects of erosion control blankets on snakes have not been thoroughly addressed (Kapfer and Paloski 2011). More research is necessary to document the impacts of erosion blankets as another potential ecological sink. Nesting success and nesting failure was documented beneath erosion control blankets, as well as adult and juvenile mortality. If collection by hobbyists is a problem at particular sites where snakes aggregate beneath erosion control blankets, this is another avenue that requires further investigation.

Overall, further habitat restoration is necessary to connect isolated populations of *O. vernalis* that are persisting in small habitat fragments. In McHenry County, large sites such as Glacial Park, Pleasant Valley, and Lake in the Hills have sufficient area to support many subpopulations of *O. vernalis.* However, burn frequency must be examined such that sufficient time has passed to allow recolonization of burned areas before they are burned again. Care must be taken to ensure that refugia are protected within each parcel during burning. In DuPage County, urban development in the eastern portion of the county has impacted *O. vernalis* occupancy. Most of the parcels in the eastern half of the county are small and are bound by high traffic roadways. The remaining populations in the western sites at West Chicago Prairie and Pratt's Wayne Preserve require greater study and protection. More research is warranted to conduct mark-recapture studies of the known remaining populations so that specific recovery actions may be better assessed. Mark-recapture studies focused on the remaining populations would provide valuable information on survival of each sex and age class in response to habitat management and restoration practices, allowing a more detailed assessment of the likelihood of population persistence into the future.

Tables and Figures

Table 1. Total area of survey sites and corresponding number of transects in DuPage County sites.

Site	Total Area (acres)	Number of Transects
Blackwell Preserve	1,379	3
Churchill Woods	264	2
East Branch	525	3
James Pate Philip State Park	501	2
Night Heron Marsh	137	2
Pratt's Wayne	3,478	7
Swift Prairie	115	2
Timber Ridge	1,163	2
Waterfall Glen	2,492	2
West Chicago Prairie	358	5

Table 2. Total area of survey sites and corresponding number of transects in McHenry County sites.

Site	Total Area (acres)	Number of Transects
Alden Sedge Meadow	953	3
Barber Fen	117	2
Boger Fen	37	2
Chain O'Lakes SP	2,793	3
Fel-Pro RRR	277	3
Glacial Park	3, 410	6
Goose Lake	429	2
Hebron Peatlands	181	3
Hickory Grove	411	4
Lake Elizabeth	345	3
Lake in the Hills Fen	408	4
Larsen Prairie	8	2
North Branch	521	3
Pioneer Fen	41	4
Pleasant Valley	2073	5

Table 3. Candidate models for evaluation in occupancy estimation of smooth green snakes (*O. vernalis*) in DuPage and McHenry County Sites. Model parameters include occupancy (*Psi*) which may either be constant (.) or vary with a site covariate of burn interval (burn) or time (t); and detection probability (*p*) which may be constant (.), vary in time (t) or with sampling covariates and site covariates (burn, temperature, rainfall).

Candidate Models for Site-Specific Variation in Occupancy
Psi(.) p(t*Burn)
Psi(.) p(t)
Psi(.) p(Burn)
Psi(.) p(.)
Psi(.) p(t*Rain)
Psi(.) p(t*Temp)
Psi(Burn) p(t)
Psi(.) p(Rain)
Psi(.) p(Temp)
Psi(Burn) p(.)
Psi(Burn) p(t*Rain)
Psi(.) p(t*Temp+t*Rain)
Psi(.) p(Rain+Temp)
Psi(t) p (.)
Psi (t) p(t)
Psi(t*Burn) p (.)
Psi (t*Burn) p (t)

Table 4. Candidate models for examination of landscape-scale factors influencing *Opheodrys vernalis* occupancy. Psi (.) indicates the null model for constant occupancy across sites. Each model was examined for 25 m, 50 m, 100 m, 250 m, 500 m, and 1000 m scales. Detection probability was held constant.

Models
Psi(.)
Psi (Open Canopy)
Psi (Development)
Psi (Agriculture)
Psi (Open Canopy + Development)
Psi (Open Canopy + Agriculture)
Psi (Development + Agriculture)

Table 5. Minimum number known alive for *Opheodrys vernalis* captures by sex and age class, with additional nesting success information for McHenry and DuPage County sites.

Site	Age Class	Males	Females	Number of Individuals
Glacial Park	Adult		1	1
Fel-Pro RRR	Adult		1	1
Lake in the Hills Fen	Adult	1		1
Pleasant Valley	Adult	1		1
Pratt's Wayne	Adult	1		1
West Chicago Prairie	Juvenile	1	1	2 (+ 1 found dead)
West Chicago Prairie	Adult	1	3	4
West Chicago Prairie	Nests			3 nests (n = 17 eggs) 10 hatched, 3 failed, 4 missing*

*Missing eggs are addressed in the results and discussion.

Table 6. Candidate model ΔAICs, model weights (*w*), model likelihood estimates, and number of parameters (*k*). Models with variation in occupancy with time had no support and were not included in the table. The best fit model has the greatest weight and likelihood. Model parameters include occupancy (*Psi*) which may either be constant (.) or vary with a site covariate such as burn interval (burn) or through time (t); and detection probability (*p*) which may be constant (.), vary in time (t) or with sampling covariates and site covariates (burn, temperature, rainfall).

Model	ΔAIC	*w*	Model Likelihood	*k*
Psi(.) p(t*Burn)	0.00	0.41	1.00	7
Psi(.) p(t)	2.21	0.14	0.33	6
Psi(.) p(Burn)	2.25	0.13	0.32	3
Psi(.) p(.)	3.98	0.05	0.14	2
Psi(.) p(t*Rain)	4.19	0.05	0.12	7
Psi(.) p(t*Temp)	4.20	0.05	0.12	7
Psi(Burn) p(t)	4.20	0.05	0.12	7
Psi(.) p(Rain)	5.87	0.02	0.05	3
Psi(.) p(Temp)	5.95	0.02	0.05	3
Psi(Burn) p(.)	5.97	0.02	0.05	3
Psi(Burn) p(t*Rain)	6.18	0.01	0.04	8
Psi(.) p(t*Temp+t*Rain)	6.19	0.01	0.04	8
Psi(.) p(Rain+Temp)	7.83	0.01	0.02	4
Psi(t) p (t)	7.92	0.01	0.01	10
Psi(.) p (t)	8.13	0.01	0.009	6
Psi(t*Burn)p (t)	9.28	0.01	0.008	11
Psi (t*Burn) p (.)	9.54	0.01	0.008	7

Table 7. Resulting detection probabilities estimated using the best fit model: Psi(.) p(t*burn).

	May	June	July	August	September
Detection	0.36	0.44	0.36	0.07	0.07

Table 8. Ranked candidate models for landscape-scale characteristics influencing smooth green snake occupancy in DuPage and McHenry County sites. Model parameters include occupancy (*Psi*) which may vary with site covariates including percent of area with open canopy (CAN), percent of area in development (DEV), and percent of area in agriculture (AGR) within 25m, 50m, 100m, 250m, 500m, or 1000m. The null model Psi (.) p (.) indicates constant occupancy and detection probability.

Scale	Model	deltaAIC	*w*	Model Likelihood	*k*
25 m	Psi(CAN25+ DEV25),p(.)	0	0.3029	1.0000	3
	Psi(CAN25),p(.)	0.8	0.2031	0.6703	2
	Psi(CAN25 + AGR 25),p(.)	1.24	0.163	0.5379	3
	Psi(DEV25),p(.)	2.05	0.1087	0.3588	2
	Psi(.),p(.)	2.18	0.1019	0.3362	2
	Psi(AGR25),p(.)	2.65	0.0805	0.2658	2
	Psi(DEV25+AGR25),p(.)	4.05	0.04	0.132	3
50 m	Psi(CAN50 +DEV50),p(.)	0	0.1921	1.000	3
	Psi(CAN50),p(.)	0.03	0.1893	0.9851	2
	Psi(DEV50),p(.)	0.55	0.1459	0.7596	2
	Psi(.),p(.)	0.66	0.1381	0.7189	2
	Psi(DEV50 +AGR50),p(.)	0.66	0.1381	0.7189	2
	Psi(AGR50),p(.)	1.13	0.1092	0.5684	2
	Psi(CAN50 +AGR50),p(.)	1.58	0.0872	0.4538	3
100 m	Psi(CAN100 + AGR100),p(.)	0	0.4379	1.0000	3
	Psi(CAN100),p(.)	1.65	0.1919	0.4382	2
	Psi(CAN100+DEV100),p(.)	2.4	0.1319	0.3012	3
	Psi(DEV100),p(.)	3.31	0.0837	0.1911	2
	Psi(.),p(.)	3.71	0.0685	0.1565	2
	Psi(AGR100),p(.)	4.17	0.0544	0.1243	2
	Psi(DEV100+AGR100),p(.)	5.25	0.0317	0.0724	3
500 m	Psi(DEV500),p(.)	0	0.2299	1.0000	2
	Psi(DEV500 +AGR500),p(.)	0.44	0.1845	0.8025	3
	Psi(CAN500 +DEV500),p(.)	0.93	0.1444	0.6281	3
	Psi(AGR500),p(.)	0.93	0.1444	0.6281	2
	Psi(CAN500),p(.)	1.15	0.1294	0.5627	2
	Psi(.),p(.)	1.78	0.0944	0.4107	2
	Psi(CAN500 + AGR500),p(.)	2.3	0.0728	0.3166	3
1000 m	Psi(DEV1000 + AGR1000),p(.)	0	0.9473	1.0000	3
	Psi(CAN1000+ AGR1000),p(.)	8.56	0.0131	0.0138	3
	Psi(DEV1000),p(.)	8.69	0.0123	0.013	2
	Psi(AG1000),p(.)	8.97	0.0107	0.0113	2
	Psi(.),p(.)	10.18	0.0058	0.0062	2
	Psi(CAN1000),p(.)	10.32	0.0054	0.0057	2

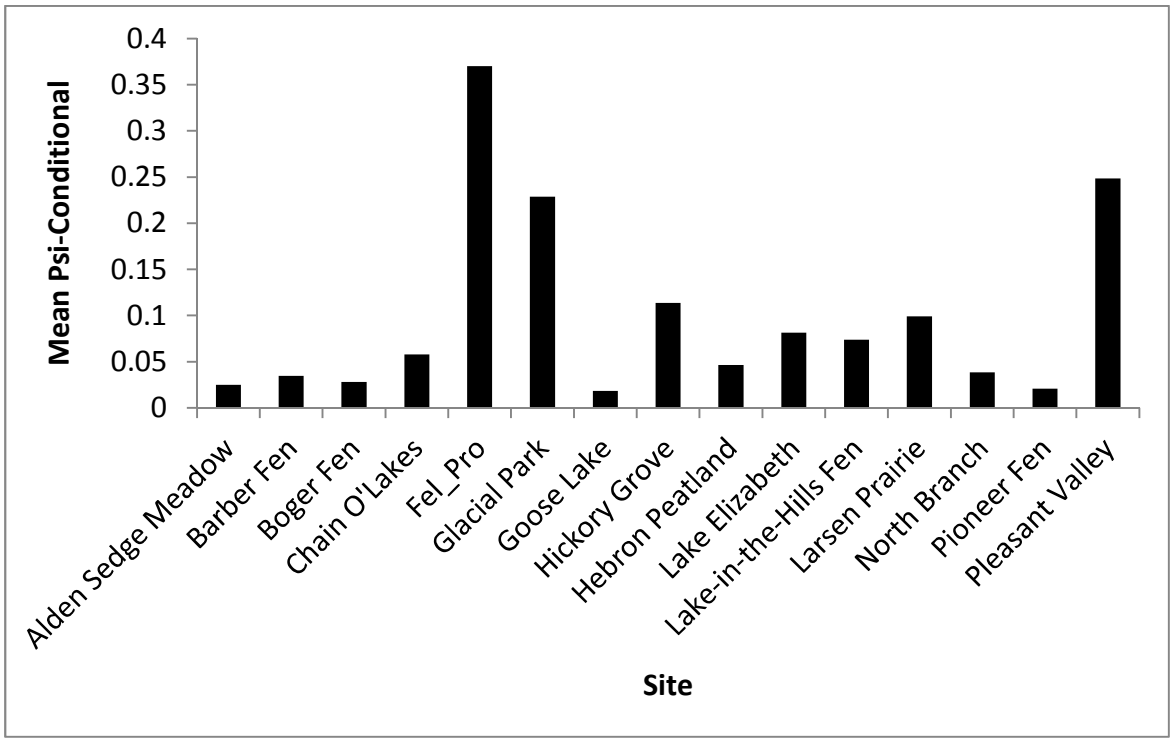

Figure 1. Mean psi-conditional (proportion of area occupied for each site given detection probability), for *Opheodrys vernalis* in McHenry County sampling sites.

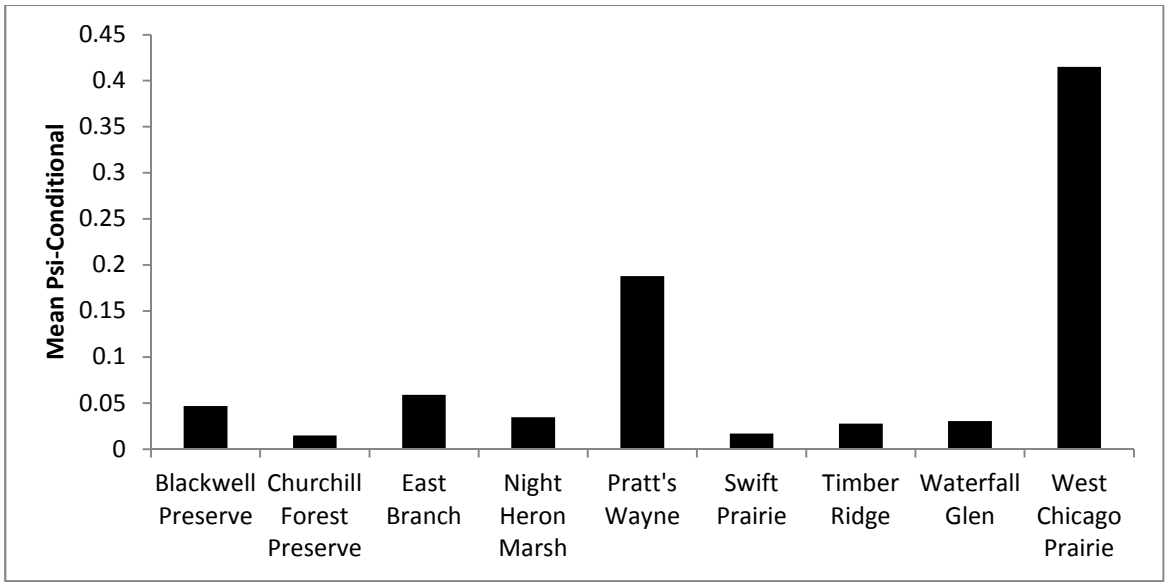

Figure 2. Mean psi-conditional (proportion of area occupied for each site given detection probability), for *Opheodrys vernalis* in DuPage County sampling sites.

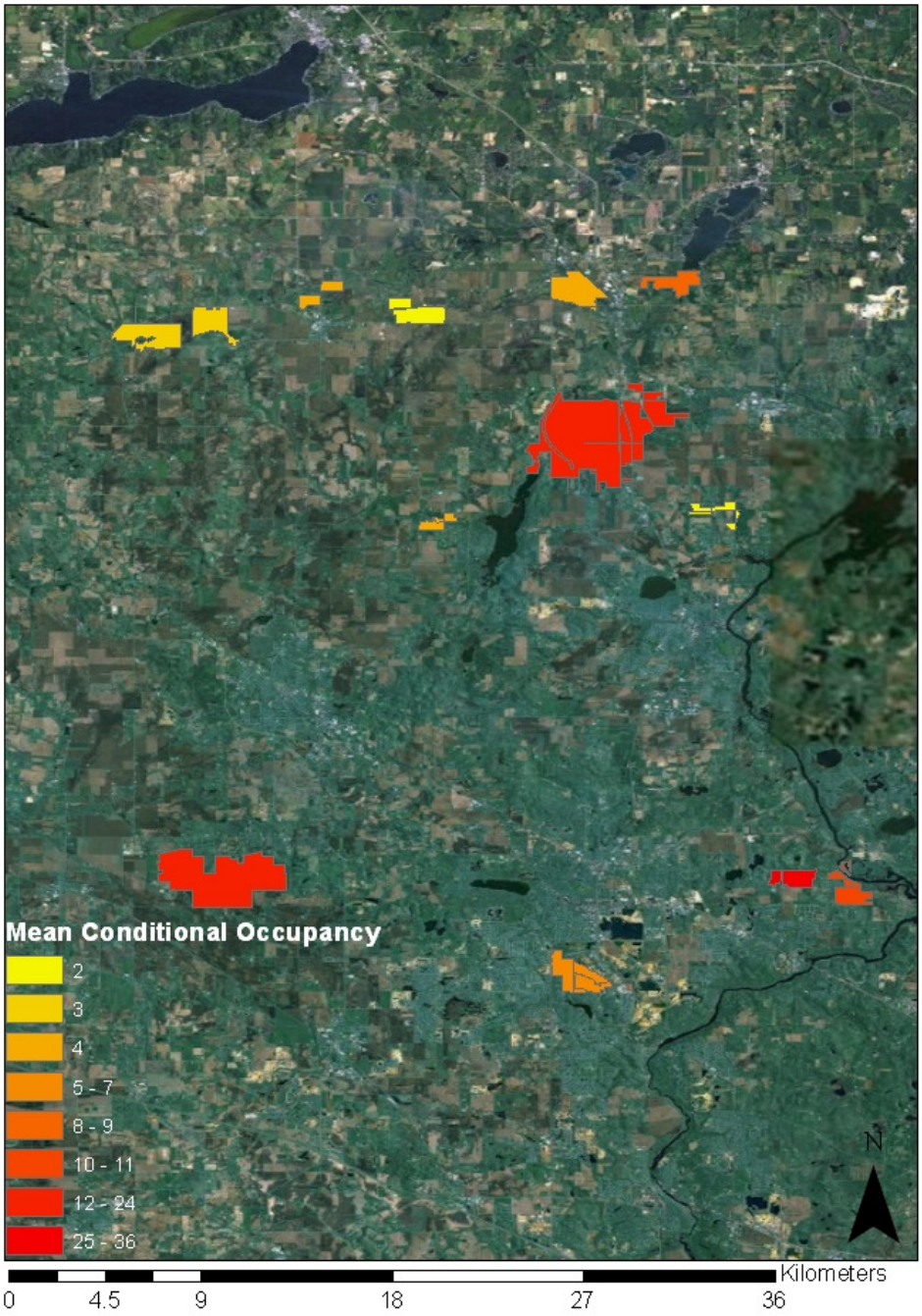

Figure 3. Map of McHenry County preserved lands scored for conditional percent of area occupied based on site-specific detection probabilities for *O. vernalis* as estimated in Program PRESENCE.

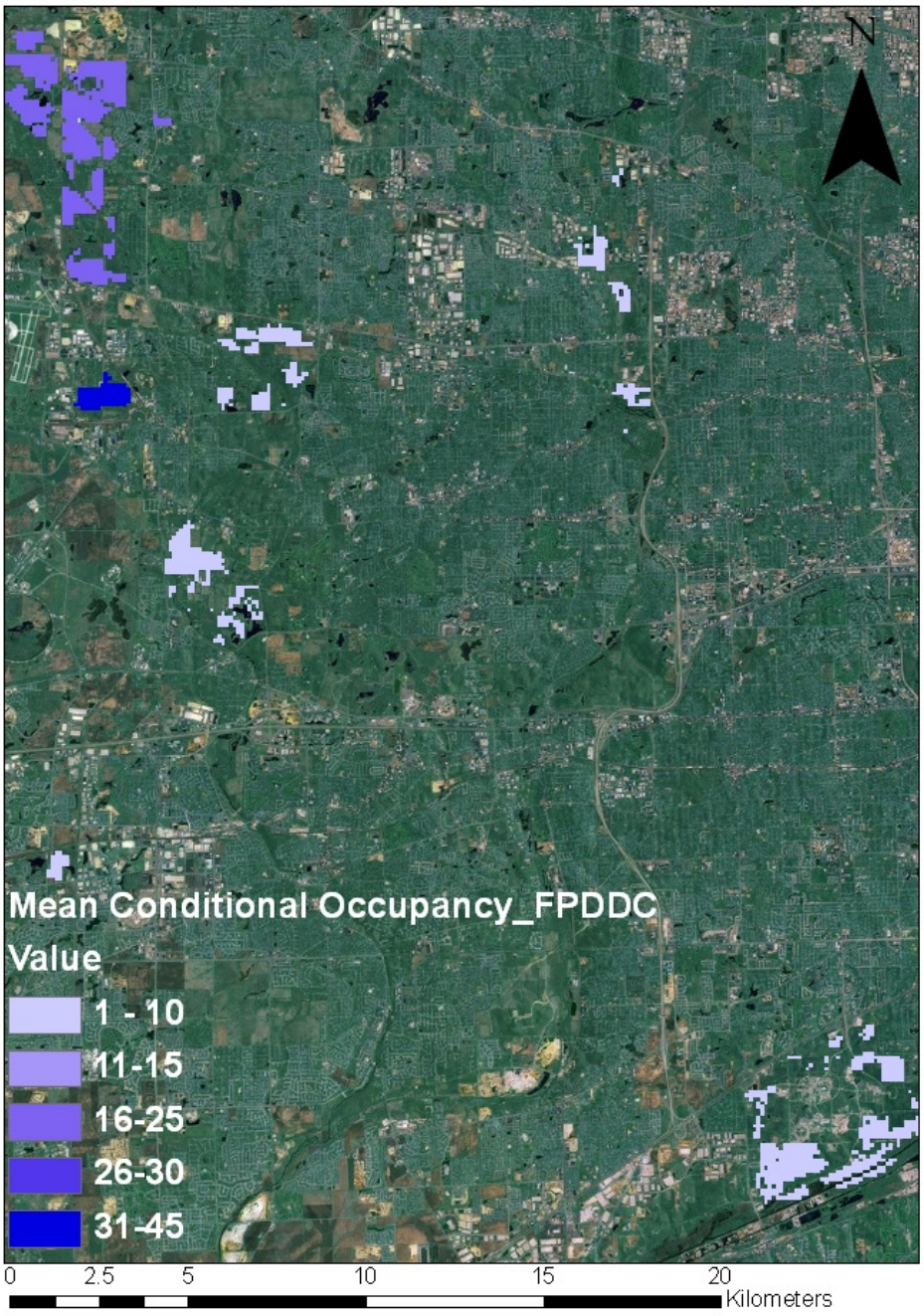

Figure 4. Map of DuPage County preserved lands scored for conditional percent of area occupied based on site-specific detection probabilities for *O. vernalis* as estimated in Program PRESENCE.

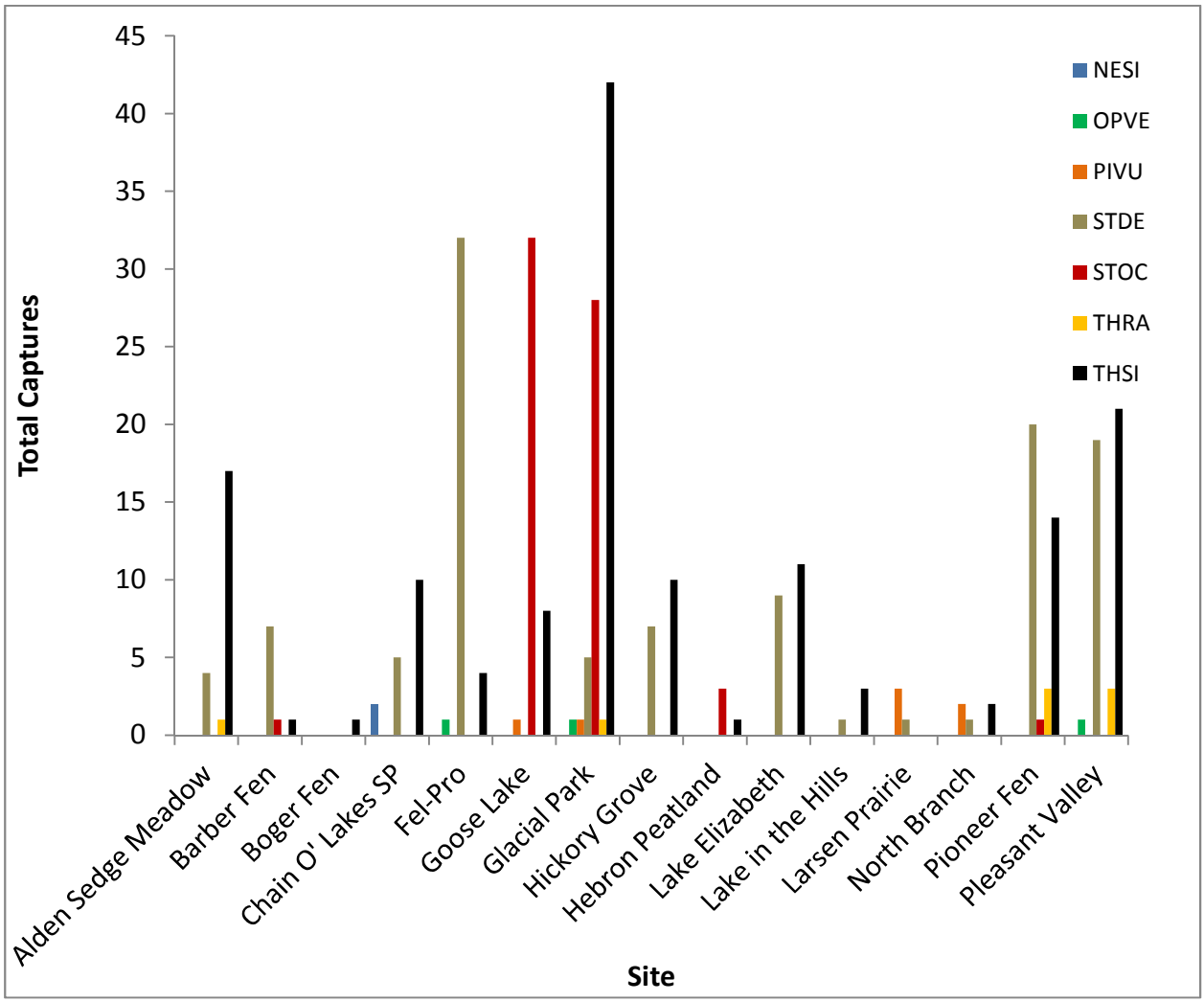

Figure 5. Total captures of each species by site in McHenry County Sites. Species include smooth greensnakes (*Opheodrys vernalis* – OPVE), eastern foxsnake (*Pituophis vulpinus*), DeKay's brownsnake (*Storeria dekayi*—STDE), redbelly snake (*Storeria occipitomaculata*—STOC), plains gartersnake (*Thamnophis radix*—THRA), and common gartersnake (*Thamnophis sirtalis*—THSI).

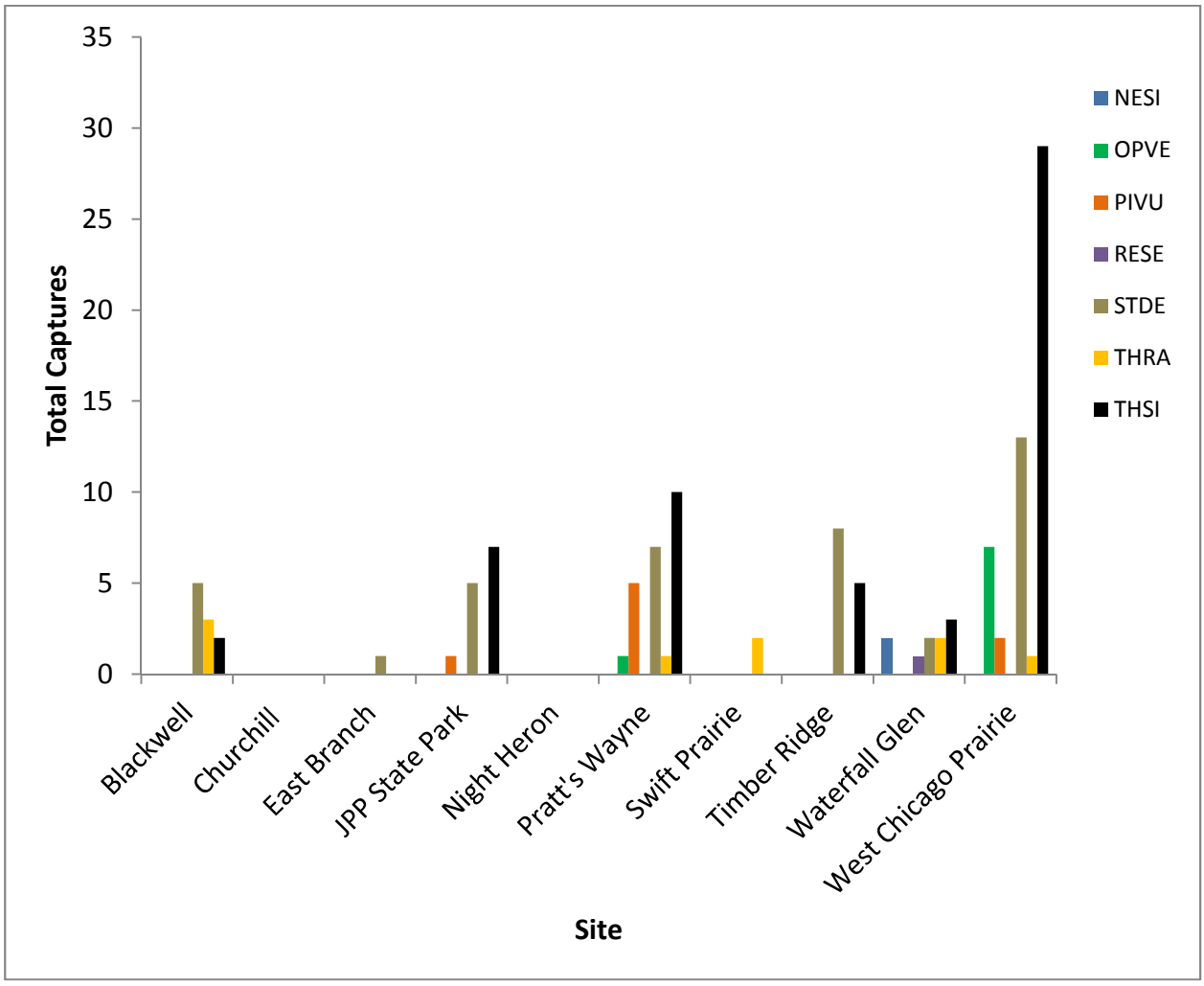

Figure 6. Total captures of each species by site in DuPage County sites. Species include northern watersnake (*Nerodia sipedon*—NESI), smooth greensnake (*Opheodrys vernalis*—OPVE), eastern foxsnake (*Pituophis vulpinus*—PIVU), queen snake (*Regina septemvittata*—RESE), DeKay's Brownsnake (*Storeria dekayi*--STDE), plains gartersnake (*Thamnophis radix*--THRA), and common gartersnake (*Thamnophis sirtalis*--THSI).

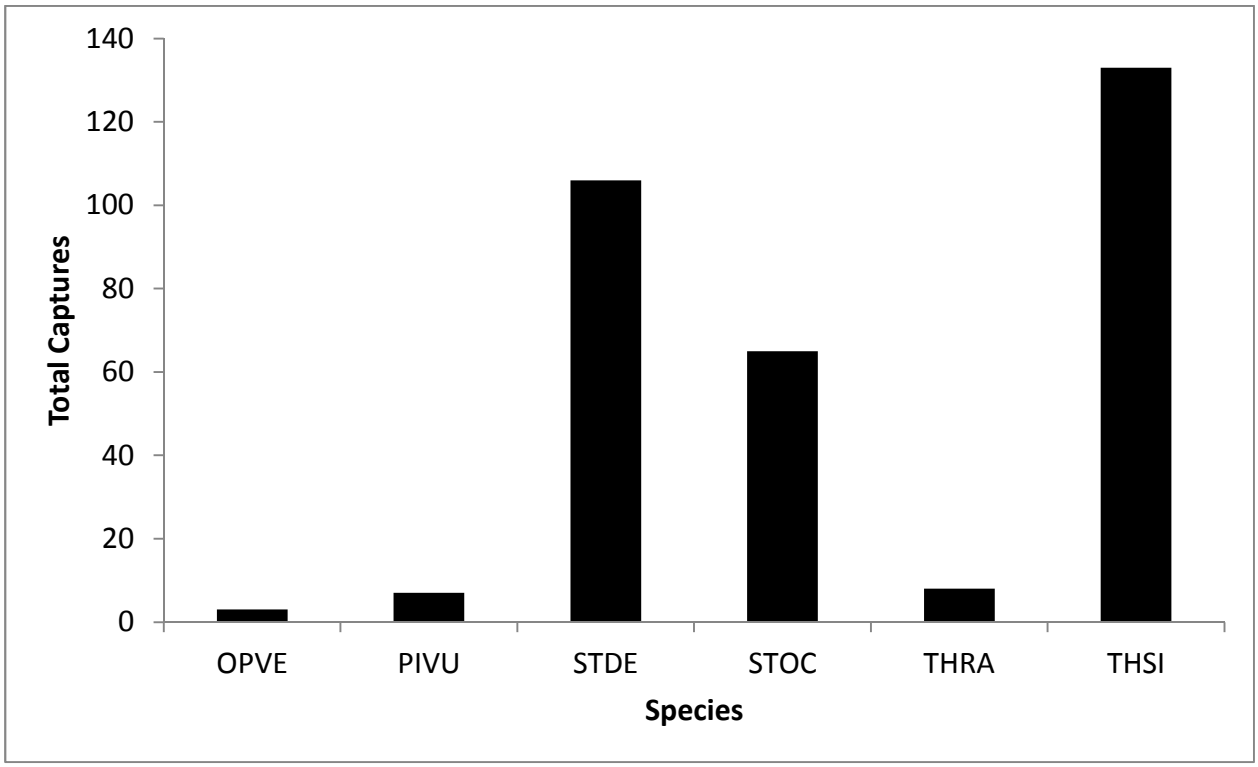

Figure 7. Snake species totals across McHenry County Sites. Species include smooth greensnakes (*Opheodrys vernalis* – OPVE), eastern foxsnake (*Pituophis vulpinus*), DeKay's brownsnake (*Storeria dekayi*—STDE), redbelly snake (*Storeria occipitomaculata*—STOC), plains gartersnake (*Thamnophis radix*—THRA), and common gartersnake (*Thamnophis sirtalis*—THSI).

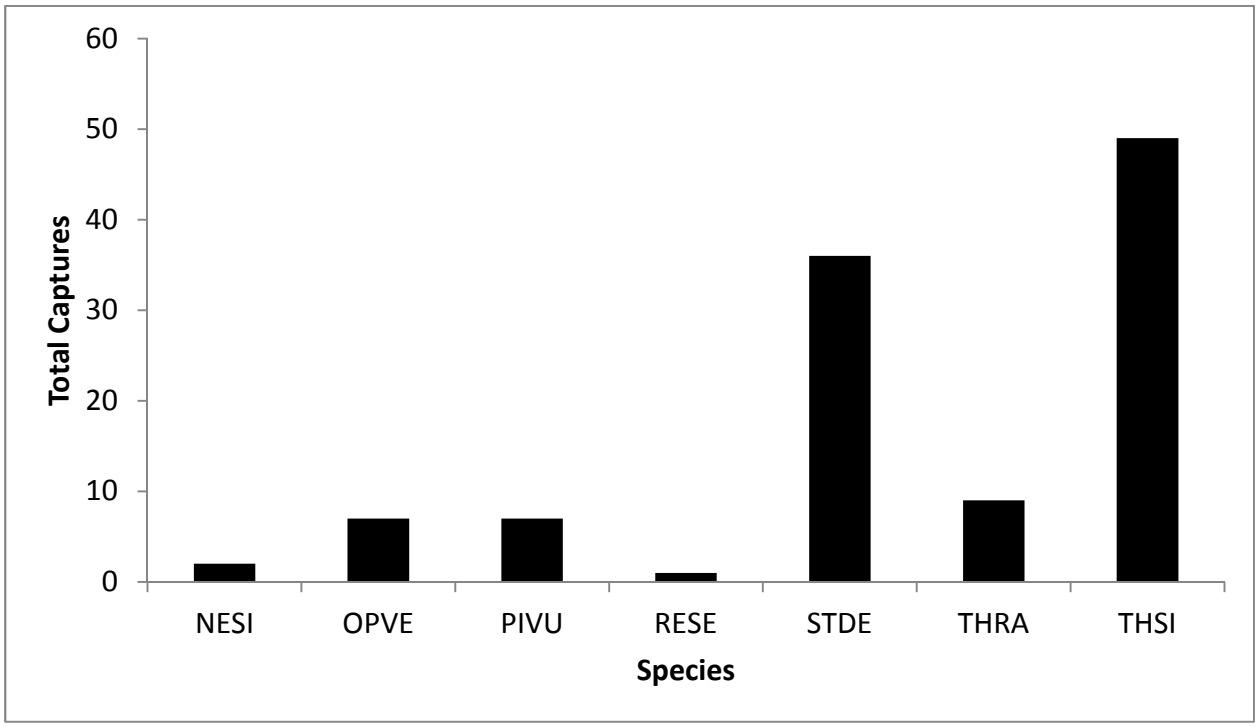

Figure 8. Snake species totals across sites in DuPage County. Species include northern watersnake (*Nerodia sipedon*—NESI), smooth greensnake (*Opheodrys vernalis*—OPVE), eastern foxsnake (*Pituophis vulpinus*—PIVU), queen snake (*Regina septemvittata*—RESE), DeKay's Brownsnake (*Storeria dekayi*--STDE), plains gartersnake (*Thamnophis radix*--THRA), and common gartersnake (*Thamnophis sirtalis*--THSI).

Literature Cited

Redder, A.J., B.E. Smith, and D.A. Keinath. 2006. Smooth Green Snake (Opheodrys vernalis): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region.

Barton, C. and K. Kinkead. 2005. Do erosion control and snakes mesh? *Journal of Soil and Water Conservation* 60:33A-35A

Cagle, N. 2008. Snake species distributions and temperate grasslands: a study from the American tallgrass prairie. *Biological Conservation* 141: 744-755.

Christiansen, J.L., and R.M. Bailey. 1993 Snakes of Iowa. Iowa Department of Natural Resources. Nongame Technical Series No. 1. 16 p.

Cox, C.L., E.S. Farrar, and J. Hey. 2005. Geographical distribution: Opheodrys vernalis. *Herpetological Review* 36:339.

Durso, A. M., J. D. Willson, and C. T. Winne. 2011. Needles and haystacks: estimating detection probability and occupancy of rare and cryptic snakes. *Biological Conservation* 144: 1508-1515.

Hines, J. E. 2006. Presence2- Software to estimate patch occupancy and related parameters. USGS-PWRC. http://www.mbr-pwrc.usgs.gov/software/presence.html.

Kapfer, J. M. and R. A. Paloski. 2011. On the threat to snakes of mesh deployed for erosion control and wildlife exclusion. *Herpetological Conservation and Biology* 6: 1-9.

Levell, J.P. 1997. A field guide to reptiles and the law. Second edition. Serpent's Tale Books, Lanesboro, MN.

Mierzwa, K.S., 1994. Patch dynamics of amphibians and reptiles in northeastern Illinois savanna landscapes, in: Fralish, J.S.,Anderson, R.C., Ebinger, J.E., Szafonim, R. (Eds.) Proceedings of the North American Conference on Savannas and Barrens, US Environmental Protection Agency, Great Lakes National Program Office, Chicago, pp. 161–165.

Oldfield, B. and J. J. Moriarty.1994. Amphibians and reptiles native to Minnesota. University of Minnesota Press Minneapolis, Minnesota.

Partners in Amphibian and Reptile Conservation (PARC). 2006. Habitat management guidelines for amphibians and reptiles of the Midwest. Technical Publication HMG-1 1st edition.

Smith, P. W.1961. The Amphibians and Reptiles of Illinois. Illinois Natural History Survey Bulletin 28: 1

Stuart, J. N., M. L. Watson, T. L. Brown, and C. Eustice. 2001.Plastic netting: an entanglement hazard to snakes and other wildlife. *Herpetological Review* 32:162-164

Walley, H. D., R. B. King, J. M. Ray, and J. Robinson. 2005a. What should be done about erosion control mesh netting and its destruction of herpetofauna? *Journal of Kansas Herpetology* 16: 26-28.

Walley, H. D., R. B. King, J. M. Ray, and J. Robinson. 2005b. Erosion mesh netting: a major threat hazard to snakes. *Bulletin of the Maryland Herpetological Society* 41: 37-39

Detailed Project Expenditures from December 31, 2012-December 31, 2013

PERSONNEL					
Name/Title		**Hourly Rate**	**Hours**	**Total**	**Source of Funds**
Allison Sacerdote-Velat, PhD, Principal Investigator		$19.25	2,078	$40,001.50	Lincoln Park Zoo/Lake County Forest Preserve District
Meghan Jedloe, Technician-DuPage County Sites		$11.00	630	$6,930.00	Dr. Scholl Conservation Internship/Lincoln Park Zoo
Alyssa Lochen, Technician-McHenry County Sites		$11.00	525	$5,775.00	McHenry County Conservation District
			Subtotal	**$52,706.5**	
TRAVEL					
Description		**Item Rate**	**Quantity**	**Total**	**Source of Funds**
P.I.'s project mileage		0.565 per mile	1294	$731.17	Illinois Special Wildlife Projects Fund
DuPage technician's project mileage		0.565 per mile	1284	$725.80	Illinois Special Wildlife Projects Fund
McHenry technician's project mileage		0.565 per mile	1518	$857.67	McHenry County Conservation District
			Subtotal	**$2,314.64**	
MATERIALS/SUPPLIES					
Description	**Vendor**	**Price/item**	**Quantity**	**Total**	**Source of Funds**
Wooden coverboards (Purchased based on availability at multiple store locations between April 5-May 18, 2013)	Home Depot (multiple locations: Glendale Heights, Addison, and Richmond, Illinois)	$13.97 (in 4'x8' sheets, cut down to 2'x2')	39	$543.03	Illinois Special Wildlife Projects Fund
Rubber mats (used conveyor belt)	Sycamore Quarry	Donated	5 used belts	$0.00	Donated by Sycamore Materials
			Subtotal	**$543.03**	
COSTS					
Total Expenditures				**$55,564.17**	
Expenditures Covered by IDNR Special Wildlife Projects Fund				**$2,000.00**	
Expenditures Covered by Other Sources				**$53,564.17**	