

EVALUATING THE INFLUENCE WHITE-TAILED DEER HAVE ON WETLAND
VEGETATION TYPES WITH RESPECT TO WETLAND BIRDS AT SHIAWASSEE
NATIONAL WILDLIFE REFUGE, SAGINAW, MICHIGAN

By

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ABSTRACT

EVALUATING IMPACTS WHITE-TAILED DEER HAVE ON WETLAND VEGETATION TYPES WITH RESPECT TO WETLAND BIRDS AT SHIAWASSEE NATIONAL WILDLIFE REFUGE, SAGINAW, MICHIGAN

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White-tailed deer (*Odocoileus virginianus*), can be keystone herbivores in forest ecosystems and greatly impact forest conditions. Results of previous deer herbivory research could cause biologists concern when managing wetlands as suitable habitat for migratory waterfowl since high levels of herbivory can negatively impact plant communities. There is a knowledge gap on how deer use of wetland vegetation types may affect bird use of those same wetlands. Our objectives were to 1) evaluate white-tailed deer habitat suitability within a landscape dominated by wetlands, 2) quantify and compare use of wetland vegetation types by white-tailed deer to use by wetland bird communities, and 3) quantify white-tailed deer herbivory within various wetland types. We classified 1 x 1 m aerial imagery data in ArcGIS v10.0 and developed a white-tailed deer habitat suitability index (HSI) model. We conducted driving surveys during crepuscular hours alternating morning and evening sampling times per week from May – August 2011 and 2012 in 3 wetland types. We constructed exclosures and paired them with open areas in moist soil, perennial marsh, lakeplain prairie, and bottomland hardwood forest vegetation types where we measured horizontal cover, vertical cover, species richness, total above ground biomass, and seed biomass. Wetlands provide highly suitable deer habitat, deer are using wetlands but not influencing wetland bird communities, and current deer herbivory is not negatively impacting the composition and structure of wetland plant communities. These results are being used to help guide management decision making at Shiawassee National Wildlife Refuge.

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PREFACE

This thesis is organized into 3 chapters and 2 appendices. The chapters generally follow the guidelines for manuscripts submitted to The Wildlife Society Bulletin. Chapters 1-3 were formatted as complete manuscripts so some redundancy may occur (e.g. study area description and some content within the introductions). Chapter 1 describes results on habitat suitability of wetland vegetation types for white-tailed deer within Shiawassee National Wildlife Refuge and the surrounding area. Chapter 2 describes results on deer use and bird species richness within different wetland vegetation types at Shiawassee National Wildlife Refuge. Chapter 3 describes results on white-tailed deer herbivory within 4 wetland vegetation types. Appendix A provides data sheets and locations of forest exclosures to help the Shiawassee National Wildlife Refuge staff to continue monitoring these sites and obtain data for a long-term study. Appendix B highlights how the results of this research project have been disseminated within the scientific community and also with outreach projects. Photo documentation of exclosure sites has been archived at Shiawassee National Wildlife Refuge and with Dr. Henry Campa, III at Michigan State University. An animal use exemption form dated December 7, 2010 addressed to Dr. Henry Campa, III, was received from the Institutional Animal Care and Use Committee because we were not handling wildlife for this study.

INTRODUCTION

White-tailed deer (*Odocoileus virginianus*) are adaptable organisms, which inhabit and use many different vegetation types and environments from forests and agricultural fields to urban settings (Rooney 2001). Deer are an important part of the Midwest landscape because they can be keystone herbivores in forest ecosystems and, thereby, potentially impact wildlife communities (Vercauteren and Hygnstrom 1998, Rooney 2001, Rooney and Waller 2003). Deer have also been shown to negatively impact forest vegetation types by altering the composition, structure, and biomass of understory vegetation and reducing recruitment and regeneration of woody plant species (Marquis and Grisez 1978, Horsely and Marquis 1982, Rooney 2001, Rooney and Waller 2003). Historic removal of native predators, such as the grey wolf (*Canis lupus*) and cougar (*Felis concolor*), changes in hunting regulations, and habitat modification have all also contributed to the expansion of deer populations throughout their range (Rooney 2001).

Degradation of vegetation due to browsing can be a concern for natural resource managers because a correlation between the loss of understory and reductions in abundance and diversity of insects, mammals and migratory birds has been documented for forest vegetation types (Rooney 2001, Rooney and Waller 2003). Deer herbivory can also cause a shift from one vegetation type to another. In severe cases, where deer herbivory has negatively affected plant communities by reducing the structure, composition or productivity, deer have been able to set back succession by consuming the entire understory leaving only ferns and less palatable plants (Rooney 2001, Urbanek et al. 2012). Deer habitat, however, is not composed of just forest vegetation types but also encompasses many different wetland vegetation types (Pusateri 2003, Hiller 2007).

Deer use of wetlands can cause concern for natural resource managers because wetland vegetation types can provide important life requisites for many bird species including waterfowl, wading birds and shorebirds (Burger et al. 1996, Hafner 1997, Colwell and Taft 2000, Steven et al. 2003, Stafford et al. 2010, O'Neal et al. 2012). The National Wildlife Refuge System, run by the U.S. Fish and Wildlife Service, is one way the federal government acquires land to create habitat and conserve these important wetlands for migratory birds and endangered species, and is the only federal agency responsible for creating and maintaining habitat for migratory birds (USFWS 2012). Nationally, there is a minimum of one National Wildlife Refuge per state, and many of the National Wildlife Refuges are located along major flyways in an effort to conserve important land for migratory birds (USFWS 2012).

Wetland vegetation types provide important habitat for feeding stopover sites during migration for waterfowl as well as important over-wintering sites (Stafford et al. 2010). Shorebirds also use wetlands for feeding and foraging sites along migration routes (Bookhout et al. 1989, Burger et al. 1996). Large numbers of shorebirds and waterfowl can be seen using different wetland vegetation types during fall and spring migration times for foraging and resting sites, most heavily from May through June and September through October (Burger et al 1996, Chaulk and Turner 2007). While shorebirds and waterfowl can be seen using wetlands heavily during spring and fall migration, wading birds are also dependent on wetland vegetation types for feeding sites (Colwell and Taft 2000). Wetland vegetation types are also important resting, breeding and brood rearing sites for waterfowl and wading birds (Hafner 1997, Stevens et al. 2003). Wetland vegetation types are often optimal sites for nesting and brood rearing because of the amount of structural diversity they can provide for different species (Hafner 1997, Stevens et al. 2003).

The challenges presented by white-tailed deer herbivory have not necessarily been limited to forest vegetation types. If deer can affect the distribution and abundance of plant and wildlife species while changing the community structure at more than one trophic level in forest vegetation types (Hanley 1996, Waller and Alverson 1997), then it can be projected they may change other vegetation types in a similar manner. Coniferous and deciduous forest vegetation types can be important vegetation types for white-tailed deer habitat; however mixed wetland, lowland shrub and lowland deciduous are also important vegetation types (Hiller 2007). White-tailed deer have also been documented to use wetland vegetation types extensively to fulfill life requisites (Larson et al. 1978, Hiller 2007, Gubanyi et al. 2008, Clements et al. 2011), but a knowledge gap exists on how a landscape dominated by wetlands provides suitable habitat for white-tailed deer.

OBJECTIVES

One goal of this study was to investigate how white-tailed deer were potentially impacting a landscape dominated by wetlands. Another goal was to describe the results for the manager and biologist at Shiawassee National Wildlife Refuge to help them make more effective management decisions that will help them maintain their goals and objectives for Shiawassee National Wildlife Refuge. The objectives of this study were to

1. Evaluate white-tailed deer habitat suitability within a landscape dominated by wetland vegetation types to help inform deer and waterfowl management decision making,
2. Quantify and compare use of wetland vegetation types by white-tailed deer to use by wetland bird communities, and
3. Quantify white-tailed deer herbivory within a landscape dominated by wetlands

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LITERATURE CITED

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CHAPTER 1

Quantifying white-tailed deer habitat suitability in wetland vegetation types with potential impacts to wetland bird communities

INTRODUCTION

White-tailed deer (*Odocoileus virginianus*) are adaptable organisms, which inhabit and use many different vegetation types and environments from forests and agricultural fields to urban settings (Rooney 2001). Deer densities throughout the Midwest have greatly increased from pre-settlement historic estimates of ~3.2-4.2 deer/ km² to estimates of 10-25deer/km² commonly seen today (Rooseberry et al. 1998, Rooney 2001, Rooney and Waller 2003, Kraft et al. 2004, Gubanyi et al. 2008). Deer are an important part of the Midwest landscape because they can be keystone herbivores in forest vegetation types which ultimately can impact wildlife communities (Vercauteren and Hygnstrom 1998, Rooney 2001, Rooney and Waller 2003). Deer have also been shown to negatively impact forest vegetation types by altering the composition, structure, and biomass of understory vegetation and reducing recruitment and regeneration of woody plant species (Marquis and Grisez 1978, Horsely and Marquis 1982, Rooney 2001, Rooney and Waller 2003).

The challenges of white-tailed deer herbivory has not necessarily been limited to forest vegetation types. If deer can affect the distribution and abundance of species while changing the community structure at more than one trophic level in forest vegetation types (Hanley 1996, Waller and Alverson 1997), then it can be projected they may change other vegetation types in a similar manner. Coniferous and deciduous forest vegetation types can be important vegetation types for white-tailed deer habitat; however mixed wetland, lowland shrub and lowland deciduous are also important vegetation types (Hiller 2007). White-tailed deer have also been documented to use wetland vegetation types extensively to fulfill life requisites (Larson et al.

1978, Hiller 2007, Gubanyi et al. 2008, Clements et al. 2011), but a knowledge gap exists on how a landscape dominated by wetlands provides suitable habitat for white-tailed deer.

Understanding how much wetland vegetation types contribute to deer habitat is important because wetlands are often managed for species other than white-tailed deer (Gray et al. 1999, USFWS 2010). For example, wetland vegetation types within the National Wildlife Refuge System are managed for waterfowl because waterfowl use wetlands for feeding, resting, and nesting areas (USFWS 2010). Areas with restricted hunting opportunities and riparian areas often have high deer densities, which can be a concern for National Wildlife Refuge managers and biologists since refuges often have these same characteristics (USFWS 2010, Clements et al. 2011).

Food availability within wetland vegetation types is also important because migratory waterfowl use wetlands as stopover sites along migration routes for resting and replenishing energy reserves (Bookhout et al. 1989). Waterfowl feed largely on seeds, roots and, herbaceous growth of aquatic and wetland plants (Low and Bellrose 1944). Just 2 hours of flight can result in 0.5-1.5 days of feeding and resting before some waterfowl are able to continue migration, while 14 hours of flight can result in a range of 5-12 days of feeding and rest (Bookhout et al. 1989). Because aquatic and wetland plants also provide foods for white-tailed deer, understanding how wetland vegetation types contribute to white-tailed deer habitat suitability is therefore, essential in understanding their potential impact to waterfowl in landscapes dominated by wetlands. Classifying a landscape into different vegetation types can help managers predict successional trajectory or site potential allowing them to make more informed wildlife habitat management decisions based on ecological characteristics that lead to conservation and sustainability of natural resources on a landscape scale (Felix et al. 2004, Felix et al. 2007, Felix

and Campa 2010). Our objective was to evaluate white-tailed deer habitat suitability within a landscape dominated by wetland vegetation types to help inform deer and waterfowl management decision making.

STUDY AREA

Our study area was located at Shiawassee National Wildlife Refuge, SNWR, in the eastern lower peninsula of Michigan in Saginaw County (USFWS 2010, USDA 1997). SNWR sits on many different commonly flooded soils such as sandy-loams, Misteuay silty clays, fluvaquents and mucks along with some soils that are infrequently flooded; sloan silt loam and sloan-ceresco complexes (USDA 2009). The 3,845 ha refuge is composed primarily of 75% bottom-land hardwood forests while the remaining 25% is rivers, perennial marshes, moist soil units, lakeplain prairies, and crop lands (USFWS 2010). The adjacent landscape was composed of wetland vegetation types, agriculture fields, and deciduous forest vegetation types. SNWR experiences temperate climate conditions with an average yearly temperature of 8.3°C, temperatures ranging from 8.0°C to 32.2°C during the growing season with highs and lows throughout the year observed in August and January respectively (National Weather Service 2007).

SNWR is an important stopover site for over 270 species of migratory birds annually and is located on some of Michigan's most productive wetlands. Thousands of birds have been observed daily using the refuge during fall and spring migrations (USFWS 2010). The only current management strategies being conducted are water manipulations of the perennial marshes and moist soil units accompanied by spraying, mowing, and disking moist soil units as needed to

set back succession (Gray et al. 1999, Steven Kahl, SNWR manager, Eric Dunton, SNWR wildlife biologist personal correspondence).

METHODS

We used a white-tailed deer habitat suitability index, HSI, model developed by Felix (2003) in combination with previous research on deer habitat use to evaluate the habitat suitability of SNWR and the surrounding landscape. This model allows managers to assess the landscape's potential to provide spring and summer habitat, fall and winter food and thermal cover sources for white-tailed deer. We used the portion of the model for assessing spring and summer habitat because we wanted to understand how the areas managed for waterfowl and surrounding area corresponded to suitable deer habitat during the growing season (Felix 2003, Hiller 2007). These results would potentially be useful for managers to understand if deer would be competing with waterfowl for food sources and how deer might potentially be impacting the plant communities within those managed impoundments.

We used high resolution (1 x 1 m) 4-band imagery (2010) from the National Agriculture Inventory Program (NAIP), distributed by the Farm Service Agency with Department of Agriculture to classify land cover within the SNWR and surrounding area. Images are captured during the agricultural growing season and within each quarter quad tile $\leq 10\%$ cloud cover is present when the image is captured which allows for identifying and classifying different vegetation types (USDA 2011). The 2010 NAIP imagery for Saginaw County, Michigan was reclassified, using ERDAS Imagine, into 15 different vegetation types, and validated based on field observations. Vegetation types included: agriculture, cattails, (*Typha* spp.) deciduous, elm-ash-cottonwood (*Ulmus-Fraxinus-Populus deltoids*), aquatic emergent, forest, mudflat, open,

pine (*Pinus*), silver maple-sugar maple-oak (*Acer saccharinum-Acer saccharum – Quercus*), upland hardwood, upland hardwood – oak, urban, water, wet-open.

To analyze and quantify HSI, we used the same 3 cover classification variables developed in the Felix (2003) white-tailed deer HSI model (coniferous, deciduous, and wetland) and added 2 more cover classification variables (agriculture edge and urban) based on research indicating deer frequently use these cover types to fulfill life requisites (Williamson and Hirth 1985, Miranda and Porter 2003, Stewart et al. 2006, Hiller 2007). The coniferous variable received the highest suitability index score (100%) when a minimum of $\geq 10\%$ cover was present, using the pine classification of the cover type variables. Hiller (2007) suggested white-tailed deer, in southern Michigan, select areas with some portion of their home range containing coniferous forest vegetation type regardless of season because of the need for thermal cover. Adult female does and young fawns have been seen selecting this vegetation type which leads to the conclusion it is an important life requisite (Pusateri 2003, Hiller 2007). In southern Michigan, deer are not seen selecting for coniferous forest types as often as in more northern climates, because milder climatic conditions reduces the need for thermal cover and coniferous forest vegetation types are less abundant (Van Deelen 1995, Felix 2003, Hiller 2007).

The deciduous forest variable received suitability scores of 100% when cover ranged from 20-70% on the landscape. The score decreased when $< 20\%$ and $> 70\%$ of the landscape was deciduous forest. In areas where no deciduous forest was present, the habitat suitability score was 0.0% because in Michigan white-tailed deer habitat always includes deciduous forests (Pusateri 2003, Hiller 2007). Deciduous forests are an important vegetation type for white-tailed deer because they are a significant source of food such as browse and mast (Johnson et al. 1995, Kraft et al. 2004, Collins and Battaglia 2008).

The agriculture edge variable had a 100% suitable value when the agricultural field edge was $\leq 90\text{m}$ from a forested cover type edge with habitat suitability decreasing as the agriculture and forest edge become further apart than 90m. Deer prefer to use portions of agriculture fields no wider than 180m across or 90m away from forest edges (Williamson and Hirth 1985, Braun 1996). Agriculture vegetation types are not considered the most important vegetation type. However, adult female deer in the Midwest have been documented using them during all seasons of the year (Vercauteren and Hygnstrom 1998, Pusateri 2003, Stewart et al. 2006, Hiller 2007).

Numerous researchers have documented that white-tailed deer will frequently use urban areas for food and cover if they contained vegetation types that provided those life requisites (Hiller 2007, Storm et al. 2007, Rhoads et al. 2010). For example Hiller (2007) documented adult female white-tailed deer used urban areas in an exurban landscape but $<8\%$ of their home range was composed of this vegetation type. These findings indicated that deer will use urban areas when available but they are not essential for fulfilling life requisites (Hiller 2007, Storm et al. 2007, Rhoads et al. 2010). The urban variable received 100% white-tailed deer habitat suitability when the percentage of urban development was $\leq 20\%$, was 0 when $>20\%$ urban development was present.

The wetland variable had highest white-tailed deer habitat suitability when landscapes are composed of 10-25% wetlands. Suitability decreases if landscapes had $<10\%$ wetlands and $>25\%$ wetlands (Miranda and Porter 2003, Pusateri 2003, Hiller 2007, Gubanyi et al. 2008, Clements et al. 2011). Previous research has documented white-tailed deer using numerous wetland types to fulfill life requisites of hiding, feeding and thermal cover during all times of the year (Rongstad and Tester 1969, Larson et al. 1978, Pusateri 2003, Hiller 2007). Hiller (2007) and Pusateri (2003) observed adult female deer and fawns using numerous wetland vegetation

types throughout the growing and non-growing seasons including lowland shrub, lowland deciduous forests, and bottomland hardwood forests.

All 5 suitability index variables were combined in the following equation to obtain the overall habitat suitability for SNWR and the surrounding area.

$$\text{HSI} = (\text{conifer suitability} + 2 * \text{deciduous suitability} + 2 * \text{agriculture edge suitability} + \text{urban suitability} + 2 * \text{wetland suitability}) / 8$$

The ecological contributions of conifer cover was not weighted in this model because of the lack of coniferous forest vegetation types and relatively mild winter weather conditions when compared to more northern regions of Michigan, which led to the belief white-tailed deer would select other vegetation types to fulfill their life requisite needs. Wetland and agriculture edge suitability was weighted as twice as much as other vegetation types because of the availability on the landscape, the availability of numerous habitat components along edges, and personal visual observations of white-tailed deer frequently using these vegetation types.

We combined data from the vegetation types to assess these 5 cover classifications variables as follows: 1) Coniferous forest = pine; 2) Deciduous forest = deciduous, elm – ash - cottonwood, silver maple - sugar maple-oak, upland hardwood, upland hardwood-oak; 3) Agriculture edge = agriculture; 4) Urban = open, urban; 5) Wetlands = cattails, emergent, mudflat, wet-open. Areas classified as water received no value and were not incorporated into the model because waterways were not considered vegetation types, and therefore, did not contribute to the overall HSI. Using the classified imagery, we used a circular roving window with a radius of 900 m to quantify habitat suitability of each pixel centered within the average

home range size of a female white-tailed deer in southern Michigan (i.e., 100ha; Pusateri 2003; Hiller 2007). Suitability indices were created for each variable in the model and then combined using Map Algebra in the Spatial Analyst Toolset (ArcMap v 10) to create an overall HSI model for the landscape. HSI values were obtained on a scale of 0-100% with 0% corresponding to no suitable habitat and 100% corresponding to the habitat fulfilling 100% of the life requisite needs for white-tailed deer.

We first assessed habitat suitability within the SNWR boundary and compared mean pixel HSI values to the area surrounding SNWR within a 100ha buffer zone, using a two-tailed t-test. We then compared mean pixel HSI values on a finer scale among 5 different wetland vegetation types within SNWR using a Tukey's honestly significant difference (HSD) test. We were able to conduct the fine scale analysis within SNWR's boundary because personal field observations and refuge vegetation classifications allowed us to adjust general land cover classes (e.g., emergent wetland) to more specific vegetation classifications (e.g., cattail, mudflat). Personal field observations could not be done outside the refuge boundary, which impeded finer scale data analysis among different wetland vegetation types for outside the refuge boundary. We used the natural breaks classification scheme in ArcMap to evaluate habitat suitability on a finer scale. We chose 4 classes, low 0.0-33 HSI, medium-low 33.1-53, medium-high 53.1-68, and high 68.1-86.

RESULTS

We ran the HSI model for SNWR and the surrounding area (Fig. 1.1). There was no significant difference between mean pixel HSI values of the SNWR (63.8%) and the surrounding area (64.6%) ($P>0.10$) (Table 1.1). Within SNWR, the south and east portions had the highest

habitat suitability values (Fig. 1.1). There is also a pocket of medium-low habitat suitability bordering the south side of the largest water body, the Shiawassee River, running through the northern half of SNWR. Another pocket of medium-low habitat exists in the northeast most portion of the refuge. This portion of the refuge is surrounding by urban development to the north, east, and west, with deciduous forest vegetation types located to the south west (Fig. 1.1). The remainder of the refuge (36%) is classified as medium-high habitat. Proportionally within the refuge boundary there are 0%, 24%, 36%, and 40% suitable habitat in the low, medium-low, medium-high and high categories, respectively (Table 1.2).

The area surrounding SNWR (within 100ha from SNWR boundary) was classified as high habitat suitability on the south and east sides of the refuge, medium-high with small pockets of medium-low habitat on the west side, medium-high and high suitability on the north west side, and medium-low with low suitability on the north east side of SNWR's boundary (Fig. 1.1). Proportionally we saw 8% low habitat suitability, 12% medium-low habitat suitability, 24% medium-high habitat suitability, and 56% high habitat suitability (Table 1.2).

When a finer scale analysis was taken to assess white-tailed deer habitat suitability within SNWR's boundary, we evaluated 5 of the primary vegetation types; moist soil, perennial marsh, lakeplain prairie, bottomland hardwood forest, and agriculture. We found moist soil vegetation types to have the highest average HSI of 73.8% followed by bottomland hardwood forest, lakeplain prairie, agriculture and perennial marsh with 70.7%, 69.7%, 63.6% and 53.3% respectively (Table 1.1). Moist soil vegetation types showed 0.0% low and medium-low habitat suitability, 32.0% medium-high habitat suitability, and 68% high habitat suitability. The perennial marsh vegetation type had the lowest average HSI with 0.0% low habitat suitability, 48.0% medium-low habitat suitability, 52.0% medium-high habitat suitability and 0.0% high

habitat suitability on the landscape (Table 1.2). The lakeplain prairie vegetation type had 0.0% low and medium-low habitat suitability, 28.0% medium-high habitat suitability, and 72.0% high habitat suitability on the landscape (Table 1.2). Bottomland hardwood forests vegetation had 0.0% low and medium-low habitat suitability, 36.0% and 64.0% habitat suitability was found in the medium-high and high classifications respectively (Table 1.2). The agriculture vegetation type had 0.0% low habitat suitability, 28.0% habitat suitability for medium-low and medium-high classifications, and 44% high habitat suitability (Table 1.2).

We compared the average HSI values among the different vegetation types within SNWR boundary to one another and found, moist soil vegetation types offered 20.5% and 11.2% significantly greater habitat suitability than perennial marsh and agriculture vegetation respectively but did not offer significantly different habitat suitability than lakeplain prairie and bottomland hardwood forest vegetation types. Lakeplain prairie vegetation types offered 16.4% and 7.1% significantly greater suitable habitat than perennial marshes and agriculture fields respectively. Bottomland hardwood forests offered 17.4% and 8.1% significantly greater suitable habitat than perennial marshes and agriculture fields respectively. Agriculture fields offered 9.3% significantly greater suitable habitat than perennial marshes (Table 1.1).

DISCUSSION

Managing white-tailed deer in landscaped dominated by wetlands may be just as challenging for natural resource managers as it is for those managing deer in landscapes dominated by forest vegetation types. White-tailed deer have the potential to be keystone herbivores and can dramatically change the structure, composition, and productivity of plant communities in forest vegetation types (Marquis and Grisez 1978, Horsely and Marquis 1982,

Rooney 2001, Rooney and Waller 2003). Pusateri (2003) and Hiller (2007) documented that deciduous forest vegetation types are important components of white-tailed deer habitat but wetland vegetation types can also encompass a large portion of deer home ranges. Landscapes dominated by some wetland types can provide areas of high habitat suitability for white-tailed deer. On SNWR's landscape 76% of SNWR was classified as medium-high to high habitat suitability while the area surrounding SNWR was 80% medium-high to high habitat suitability. Landscapes, such as many National Wildlife Refuges, dominated by wetlands that provide high HSI values and large amounts of the adjacent landscape proportionally as medium-high and high habitat suitability for white-tailed deer could see negative impacts to the plant communities from high deer densities similar to those affects seen by previous research from Marquis and Grisez (1978), Rooney (2001), and Rooney and Waller (2003).

SNWR and the surrounding area are very similar in terms of vegetation types they offer with wetlands, agriculture, and forest vegetation types present in both areas and SNWR does not offer significantly more suitable habitat than the surrounding area. Bordering the west side of SNWR is Shiawassee River State Game area owned by the Michigan Department of Natural Resources which is also managed specifically for waterfowl including the American bittern (*Botaurus lentiginosus*), mallard (*Anas platyrhynchos*), and wood duck (*Aix sponsa*) (DNR 2012). The northeast area bordering SNWR is the city of Saginaw, MI which accounts for the proportion of low deer habitat suitability (Fig.1.1, Table 1.2). In our study area, deer may not be seeking out SNWR for habitat because the surrounding area provides just as suitable habitat as SNWR, so deer would potentially be able to fulfill all of their life requisites outside SNWR's boundary. Other National Wildlife Refuges or landscapes dominated by wetlands may not have similar vegetation types on their borders. This landscape composition could be a problem for

managers in those areas since deer in lower habitat suitability areas adjacent to those boundaries may potentially move opportunistically to higher habitat suitability within refuge boundaries when seeking food sources or cover.

VerCauteren and Hygnstrom (1998), and Stewart et al. (2006), and Hiller (2007) found that deer will frequently use agricultural vegetation types for summer food sources. Wetlands that are adjacent to agriculture areas may receive higher HSI values than those that are not. Our results showed the moist soil and lakeplain prairie units had the highest and third highest average habitat suitability values respectively (Table 1.2). These units were adjacent to agricultural fields and relatively small in size (<60.3 ha) contributing to the amount of edge that white-tailed deer usually seek to meet their life requisites (Williams and Hirth 1985, Stewart et al. 2006). The size and juxtaposition to agricultural fields probably explains why these units received significantly higher HSI scores than the perennial marsh units and the agriculture fields. Stewart et al. (2006) found that deer prefer to feed in the edge of fields surrounded by forests. All of the moist soil and lakeplain prairie units were bordered on at least one side by forest vegetation types which may also have contributed to their high habitat suitability scores. Managers and biologists of National Wildlife Refuges may expect to see higher habitat suitability for white-tailed deer in wetlands with similar characteristics.

The perennial marsh vegetation type had the lowest average habitat suitability primarily because some units were relatively large (>130.3ha). This configuration provided less edge when compared to the core of the units, decreasing habitat suitability because it left more area >90m from the edge of the impoundment. Williams and Hirth (1985), Braun (1996), and Stewart et al. (2006) all documented that deer prefer to feed and use areas within the edges of units, perhaps because it provides easier access to cover from predators. The larger size of these units

and that they were not adjacent to agriculture fields, favorite summer feeding sources for white-tailed deer, probably attributed to the low HSI values. The perennial marsh units also held water longer than moist soil units throughout the year. Drawdowns of water typically started in late May or early June and water was replaced in late August to early September. Some years, some units would not be drawn down at all to leave pools of water and more niches for resident and migratory waterfowl, which decreased the availability of habitat for white-tailed deer and decreased habitat suitability scores (Gray et al. 1999, Eric Dunton and Steve Kahl, Wildlife Biologist and Refuge Manager, personal correspondence). The use of water management or water level manipulations could potentially be used as a management technique to deter deer herbivory that may impact waterfowl food sources and habitat. National Wildlife Refuge managers may expect to find wetland units within their landscape that are not adjacent to agriculture fields and are larger with more of the units >90m from the edge to provide lower habitat suitability values for white-tailed deer.

The bottomland hardwood forests had the second highest average HSI value (Table 1.1) and were also the largest (237.9 ha) managed units within the refuge. The edge component is not important for these units because, being forested units they provide cover throughout the entire unit. These units shared west borders with agriculture lands which contributed to their high suitability (Williamson and Hirth 1985, Stewart et al. 2006). Another factor contributing to their habitat suitability to deer was they contained mast producing tree species such as white oak and swamp white oak (*Quercus spp.*). Having mast producing trees in a forest increases deer habitat suitability. Johnson et al. (1995) documented mast is an important food source for white-tailed deer and can compose a large portion of their fall and winter diets. On a landscape with

bottomland hardwood forests that contain mast producing tree species, natural resource managers can expect these areas to be highly suitable habitat for white-tailed deer.

Wetland habitat suitability for white-tailed deer seems to depend greatly on the proximity to agricultural fields, the size of the wetland units, and the amount of water that may be on management units. The closer the wetland vegetation types are to preferred feeding sites, like agriculture fields and mast producing trees, the greater the habitat suitability (Johnson et al. 1995, Miranda and Porter 2003, Stewart et al 2006). The larger units with less total area of the wetland units <90m from edge of the unit the lower habitat suitability since white-tailed deer seem to prefer to feed and use areas of fields within edges (Williamson and Hirth 1985, Braun 1996, Stewart et al. 2006). Overall the majority of landscapes dominated by wetlands provide medium-high to high habitat suitability for white-tailed deer.

MANAGEMENT IMPLICATIONS

Understanding how landscape components contribute to white-tailed deer habitat suitability, and ultimately to white-tailed deer abundance, is important for managers since locally abundant deer numbers in some areas can make natural resources management a challenge. Attempting to manage white-tailed deer on National Wildlife Refuges, such as SNWR, or landscapes dominated by agricultural lands and wetlands in the face of other management priorities can be challenging (Xie et al. 2001, Gubanyi et al. 2008). Providing National Wildlife Refuge managers and wildlife biologists, in landscapes dominated by wetlands, with a white-tailed deer habitat suitability model can be useful to demonstrate areas of relatively high to low habitat suitability and where they might expect the greatest impacts from deer, since landscapes dominated by wetlands are often managed for species other than white-tailed deer. If white-

tailed deer use is substantial within wetland vegetation types, white-tailed deer may potentially change the vegetation composition and structure and, therefore, the successional trajectories of those wetland vegetation types (Horsely and Marquis 1982, Hanley 1996, Roosenberry and Wolf 1998, Rooney 2001, Rooney and Waller 2003).

With a better understanding of how landscape components contribute to deer habitat suitability, managers and biologists will be able to more effectively plan field/impoundment size with wetland restoration or mitigation in mind (Hanley 1996). Managers and biologist can anticipate higher levels of deer herbivory in wetland fields/impoundments that provide highest habitat suitability values. This will help managers when making decisions and providing habitat for migratory and resident waterfowl within wetland vegetation types.

National Wildlife Refuges face challenges when managing their landscapes because one goal of the U.S. Fish and Wildlife Service is to provide adequate habitat for resident and migratory waterfowl (USFWS 2010). Meeting this goal may be compromised in the face of locally abundant deer using the same vegetation types as bird communities. Using this model will help them understand how their landscape can provide habitat for white-tailed deer and will help tailor management decision making at a landscape level.

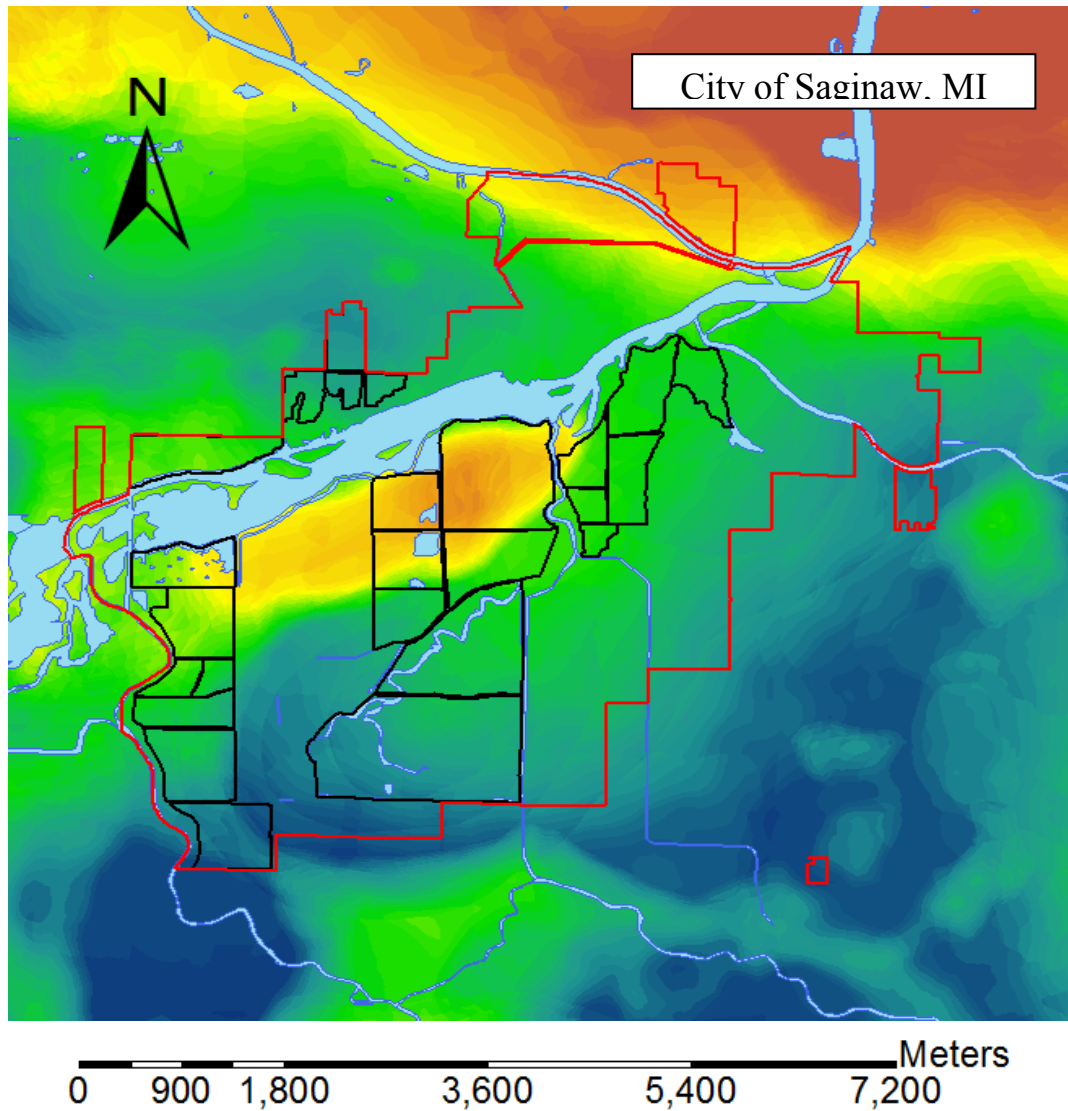
Table 1.1. Average habitat suitability index (HSI) values (standard errors) for Shiawassee National Wildlife Refuge, the surrounding landscape, and specific vegetation types within the refuge (2011-2012 growing season, Michigan).

Vegetation Type	Average HSI value (%)
Outside SNWR boundary	64.6 (3.1)
Within SNWR boundary	63.8 (2.5)
Moist Soil	73.8 A ^a (1.5)
Perennial Marsh	53.3 B (1.7)
Lakeplain Prairie	69.7 A (0.6)
Bottomland Hardwood Forest	70.7 A (0.9)
Agriculture	62.6 C (2.6)

^a Means with the same letters were not statistically different from one another (Tukey's honestly significant difference (HSD) test, HSD =5.01).

Table 1.2. Percent of each habitat suitability index (HSI) value classifications for outside Shiawassee National Wildlife Refuge, within Shiawassee National Wildlife Refuge, and 5 vegetation types within Shiawassee National Wildlife Refuge (2011-2012 growing season, Michigan). Low = 0-33.0, medium-low =33.1-53.0, medium-high= 53.1-68.0, and high=68.1-86.0 HSI values.

Vegetation Types	HSI Classifications			
	% Low	% Medium-Low	% Medium-High	% High
Outside SNWR Boundary	8	12	24	56
Within SNWR Boundary	0	24	36	40
Moist Soil	0	0	32	68
Perennial Marsh	0	48	52	0
Lakeplain Prairie	0	0	28	72
Bottomland Hardwood Forest	0	0	36	64
Agriculture	0	28	28	44



Legend

- SNWR Boundary
- Impoundment Boundary
- Water
- Habitat Suitability Index Value**
- High (86%)
- Low (0%)

Figure 1.1. Habitat suitability index (HSI) model results of Shiawassee National Wildlife Refuge and the surrounding landscape with SNWR boundary and impoundments delineated. HSI scale ranges from 0-86. For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis.

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CHAPTER 2

Habitat interaction patterns of white-tailed deer and wetland bird communities within wetland vegetation types

INTRODUCTION

Wetland vegetation types provide important life requisites for many different species of birds including waterfowl, wading birds and shorebirds (Burger et al. 1996, Hafner 1997, Colwell and Taft 2000, Steven et al. 2003, Stafford et al. 2010, O'Neal et al. 2012). The National Wildlife Refuge System, run by the U.S. Fish and Wildlife Service, is how the federal government acquires land to create habitat and conserve these important wetlands for migratory birds and endangered species, and is the only federal agency responsible for creating and maintaining habitat for migratory birds (USFWS 2012). Nationally there is a minimum of one National Wildlife Refuge per state, and many of the National Wildlife Refuges are located along major flyways in an effort to conserve important land for migratory birds (USFWS 2012).

Wetland vegetation types provide important habitat for feeding stopover sites during migration for waterfowl as well as important over-wintering sites (Stafford et al. 2010). Shorebirds also use many wetland types for feeding and foraging sites along migration routes (Bookhout et al. 1989, Burger et al. 1996). Large numbers of shorebirds and waterfowl can be seen using different wetland vegetation types during fall and spring migration times for foraging and resting sites, most heavily from May through June and September through October (Burger et al 1996, Chaulk and Turner 2007). While shorebirds and waterfowl depend on wetlands heavily during the migration seasons, wading birds are also dependent on wetland vegetation types for feeding sites (Colwell and Taft 2000). Wetland vegetation types are also important resting, breeding and brood rearing sites for waterfowl and wading birds (Hafner 1997, Stevens et al. 2003). These vegetation types are often optimal sites for nesting and brood rearing because of the amount of structural diversity they can provide and array of niches available for nesting (Hafner 1997, Stevens et al. 2003).

Waterfowl, wading birds and shorebirds are not the only species that use wetlands to fulfill life requisites. White-tailed deer (*Odocoileus virginianus*) have been documented using wetland vegetation types for hiding cover and foraging (Miranda and Porter 2003, Pusateri 2003, Hiller 2007, Gubanyi et al. 2008, Clements et al. 2011). Wetland vegetation types are among the most important vegetation types for white-tailed deer in south-central Michigan because they provided dense hiding and thermal cover and food, and in Minnesota white-tailed deer use wetlands for thermal cover and food resources throughout winter home ranges (Rongstad and Tester 1969, Hiller 2007).

Natural resource managers faced with maintaining wetlands for waterfowl, shorebirds, and wading birds may be challenged because, a knowledge gap exists on how white-tailed deer use of wetland vegetation types may affect the composition of wetland bird species communities using those same wetlands. White-tailed deer could potentially be competing with wetland bird species for space requirements to meet their resting, reproductive, and food requirements (Hafner 1997, Russel et al. 2001, Sovada 2001, Pusateri 2003, Hiller 2007). Our objective was to quantify and compare use of wetland vegetation types by white-tailed deer to use by wetland bird communities.

STUDY AREA

The study area was located at Shiawassee National Wildlife Refuge (SNWR), in the eastern lower peninsula of Michigan in Saginaw County (USFWS 2010, USDA 1997). SNWR sits on many different commonly flooded soils such as sandy-loams, Misteuaysilty clays, fluvaquents and mucks along with some soils that are infrequently flooded; sloan silt loam and sloan-ceresco complexes (USDA 2009). The refuge is approximately 3,845 ha and is 75%

bottom-land hardwood forests while the remaining 25% is rivers, perennial marshes, moist soil units, lakeplain prairies, and crop lands (USFWS 2010). The adjacent landscape was composed of wetland vegetation types, agriculture fields (corn, soybeans, winter wheat), and deciduous forest vegetation types. SNWR experiences temperate climate conditions with an average yearly temperature of 8.3°C, temperatures ranging from 8.0°C to 32.2°C during the growing season with highs and lows throughout the year observed in August and January respectively (National Weather Service 2007).

SNWR is an important stopover site for over 270 species of migratory birds annually and is located on some of Michigan's most productive wetlands. Thousands of birds have been observed at the refuge during fall and spring migrations as well as resident bird communities (USFWS 2010). Current management strategies being conducted are invasive species management, water level manipulations in the various habitat types (i.e., perennial marshes, floodplain forest, and moist soil units), and active moist soil management (e.g., spraying, mowing, and disking) as needed to set back succession (Gray et al. 1999, Steve Kahl, SNWR manager, Eric Dunton, SNWR wildlife biologist personal correspondence).

SNWR, perhaps like other National Wildlife Refuges (e.g. De Soto National Wildlife Refuge), has experienced issues related to high deer densities and deer herbivory including, complaints from nearby farmers about agricultural damage from white-tailed deer, high doe:buck ratios, low fawn weights and extensive damage to forests. In an effort to combat these issues, SNWR has reduced antlerless deer densities by using a regulated hunting season on the refuge and issuing permits on a yearly basis since early 1980's (Steven Kahl, SNWR manager, Eric Dunton, SNWR wildlife biologist, personal correspondence).

METHODS

To accomplish our objective we conducted driving surveys around SNWR (Fig.2.1). We planned to conduct a minimum of 5 surveys per impoundment per month. Surveys were conducted from sunrise to 3 hours after, and from 3 hours before to sunset, alternating morning and evening sampling times each week (Sitar 1996). Surveys were conducted May through August of 2011 and 2012 after water had been drawn off impoundments. This approach ensured deer would have the potential to use sites and making the comparison of deer use and wetland bird species richness possible. Survey routes alternated starting and ending points every time they were conducted, to reduce bias so the same impoundments were not reached at the same time during every survey (Sitar 1996).

During the driving survey, Monarch ATB 8x powered lenses were used to scan fields for wildlife. Date, time, impoundment name and vegetation type, species, and number per species of wildlife were recorded for each designated impoundment. Moist soil, perennial marsh, and lakeplain prairie vegetation types were the wetland vegetation types surveyed. Although the bottomland hardwood forest wetland vegetation type occurred on the refuge it was not included in this analysis because of the inability to observe bird species in this vegetation type from the survey routes. These impoundments contained mature trees dominated by silver maple (*Acer saccharinum*) and cottonwood (*Populus deltoides*) and were large (>125ha) making it hard to see into the impoundments making the driving survey very biased to only wildlife using the edge of impoundments. Due to the amount of disturbance caused by walking through these sites and the long settling period needed before observations could take place, other surveys such as point count, or transect surveys were not used to analyze bird species richness and deer use of the bottomland hardwood forests.

All observational data were averaged for bird species richness and white-tailed deer use for moist soil, perennial marsh and lakeplain prairie wetland vegetation types. A coarse scale analysis was first used by averaging data on a monthly basis to see if correlations existed between average number of deer and average wetland bird species richness. A finer scale analysis was used to see if any distinct temporal patterns of deer and bird use emerged when data were averaged for 15 day sampling periods. Data within the moist soil vegetation type were averaged on successional age to see if any correlations existed among the different age classes of the moist soil management units and deer and wetland bird use. We used 3 different age classes; early (<1 year since treatment), mid (1-2 years since treatment), and old (>2 years since treatment) (Table 2.1). Treatment is defined as when the management unit was set back to the earliest successional stage by first spraying the units with a general herbicide to kill all plants, mowing the unit, and/or then disking the unit. We were not able to analyze the other vegetation types based on age class because, within the perennial marsh vegetation type, we were only able to use one management unit because of sightability issues (Table 2.1). Both the lakeplain prairie management units were only used in the 2012 field season and had undergone a burn immediately prior to the start of sampling in 2012 so they were considered the same age class, early (Table 2.1). Correlation analysis was run on the data per wetland vegetation type to compare average wetland bird species richness to average deer use. This was conducted to investigate if deer use impacted the number of wetland bird species using the same wetland vegetation types.

RESULTS

The month with the highest average number of deer observed per survey route was August, with an average of 9.1 deer observed within the perennial marsh vegetation type (Table

2.3). The lakeplain prairie vegetation type had the lowest observed average deer use with averages of 0.0 seen in July and August, while the moist soil vegetation type had more deer use than the lakeplain prairie units but less than the perennial marsh impoundments with averages ranging from 2.1 to 3.4 from May through August (Table 2.3).

The lakeplain prairie vegetation type also had the lowest average bird species richness observed of 0.0 throughout the entire sampling time. The perennial marsh vegetation type had the highest averages of bird species richness observed throughout the entire sampling period ranging from 2.7 to 5.0 and had the highest bird species richness average overall of 5.0 in May (Table 2.3). The moist soil vegetation types had higher bird species richness averages than the lakeplain prairie vegetation type but less than the perennial marsh vegetation type with averages ranging from 0.0 in August to 0.8 in May (Table 2.3). The most common bird species seen throughout the sampling period were Canada goose (*Branta canadensis*) and Mallard (*Anas platyrhynchos*) but many other species were observed (Table 2.4).

When looking first at the coarse scale analysis we found no definite correlations between the average number of deer and average bird species richness using a wetland vegetation type. The correlation coefficient for the moist soil vegetation type between average number of deer and bird species richness was the largest at 0.45, while the perennial marsh vegetation type had a correlation coefficient of -0.10, and the lakeplain prairie vegetation type had a correlation coefficient of no value because no birds were observed within those impoundments (Table 2.2). In addition, there were no trends between deer use of wetland vegetation types and bird species richness observed (Fig. 2.2, Fig. 2.3).

When analyzing data on a finer scale, we found no correlations between the number of deer using a wetland vegetation type and bird species richness observed for the same vegetation type. The moist soil vegetation type again had the largest positive correlation coefficient (0.02) while the perennial marsh vegetation type had a negative correlation coefficient (-0.05). We were not able to calculate a correlation coefficient value for the lakeplain prairie vegetation type because there were no recorded observations for bird species richness. No trends over time were observed within the finer scale analysis between bird species richness and deer use of wetland vegetation types (Fig. 2.4, Fig. 2.5). There did not seem to be a positive correlation when average deer numbers increased along with average species richness or a negative correlation when average deer numbers increased, average bird species richness decreased (or vice versa).

When analyzing the data based on age class of the management units within the moist soil vegetation type we found the average number of deer observed to be highest in the late age class in the June 1st start date of the 15 day sampling period (8.3) and the lowest in the late age class in the month of May (0.0) (Table 2.5). We found bird species richness to be the highest in the early age class in May (2.2) and lowest in the early, mid and, late age classes in July and August (0.0) (Table 2.5). Based on a correlation analysis only one strong correlation occurred between average deer and bird species richness, within the early age class for the monthly sampling period (0.94) (Table 2.6). The mid and late age classes had correlation coefficients between average deer and bird species richness of 0.49 and -0.29, respectively (Table 2.6). Based on the analysis for the 15 day sampling periods we found no strong correlations between average deer and species richness. Within the early age class we found a correlation coefficient of 0.50, 0.03 within the mid age class and -0.21 within the late age class (Table 2.6). No trends

over time were observed between average deer and bird species richness observed on a monthly basis (Fig. 2.6, Fig. 2.7). No trends were observed over time for the finer scale analysis within the 15 day sampling periods for deer use and bird species richness within any of the age classes for the moist soil vegetation type (Fig. 2.8, Fig. 2.9). We also looked at total abundance of birds within moist soil age classes, perennial marshes and lakeplain prairie vegetation types. We found no trends with total abundance observed from May to August (Fig. 2.10).

DISCUSSION

We observed the highest bird species richness in May, probably because that time of the year is when birds are completing their spring migrations (Burger et al. 1996, O’Neal et al. 2012). The low species richness observed throughout June, July and August at SNWR was probably due to the fact that migration of waterfowl, wading birds or shorebirds does not begin to occur typically until September (Burger et al. 1996, Chaulk and Turner 2007, O’Neal et al. 2012). The perennial marsh units had the highest average number of bird species present. This is probably due to the fact that these units held water longer throughout the year than the moist soil and lakeplain prairie units. Draw downs of water started in June for the perennial marsh units, as opposed to May for the moist soil units and the lakeplain prairie units did not hold standing water (personal correspondence, Steve Kahl, SNWR manager and Eric Dunton, SNWR biologist). The lack of water may have reduced the availability of feeding and adequate nesting habitat for shorebirds, waterfowl, and wading birds for the moist soil and lakeplain prairie vegetation types which is why we saw lower species richness than in the perennial marshes (Hafner 1997, Stevens et al. 2003, Colwell and Taft 2007, Stafford et al. 2010).

We found only one strong correlation between deer and bird species richness in the early age class of the monthly sampling period within the moist soil vegetation type. This correlation was positive and throughout our entire sampling period (May-August) the number of deer and species richness decreased which is why this correlation coefficient was so high. One reason for finding low correlation coefficients within the remainder of the analysis might have been the limitations with the methods used to conduct the study. As the vegetation grew during the growing season it became harder to visually see wildlife within those units after mid-June. The driving survey route was conducted on roads and dikes that overlooked the managed impoundments but this did not always offer a suitable view or an advantage for sighting wildlife in impoundments with dense vegetation. This reduced the ability to see wildlife and count them, so some wildlife may have been using impoundments when a zero value was recorded. We might recommend doing occupancy modeling or developing a detection probability for each wetland vegetation type for future studies similar to this one. This might allow for a better understanding of what species of wetland birds and how per species are using wetland vegetation types.

Another reason for low correlation values might have been because deer are herbivores and, therefore, do not threaten waterfowl, wading birds or shorebirds (Butler and Vennesland 2001, Russel et al. 2001, Sovada et al. 2001, West and Messmer 2004). Deer and birds were seen within 15m of one another feeding and using the wetlands. White-tailed deer were probably not perceived as a threat to the different bird species using those same wetland vegetation types so their behavior and use of those wetlands probably was not altered when white-tailed deer were present. The presence of feeding white-tailed deer within wetland vegetation types was probably also not perceived as a threat to waterfowl, wading birds and shorebirds because they all feed on

different food sources. Waterfowl feed on seeds, roots, and shoots of aquatic and wetland plants (Low and Bellrose 1944, O'Neal et al. 2012), wading birds feed on small fish and aquatic organisms (Butler and Vennesland 2000), and shorebirds feed on small invertebrates within mudflats (Burger et al. 1996). Daigel et al (2004) and Stewart et al. (2006) documented deer feeding heavily in crop fields during the summer months when they were available, indicating croplands are some preferred food sources for white-tailed deer. Johnson et al. (1995) also found woody plant species materials (i.e.. leaves and shoots) to compose a large portion of white-tailed deer diets. Crops and woody plants were not within the boundary of any of the wetland vegetation types within our study area but those food sources were within SNWR and in close proximity to the wetlands. We can infer the deer we saw within this study were probably traveling through the wetland sites, maybe foraging on some plants but were most likely seeking out those preferred or favorite food sources nearby. Because wading birds and shorebirds do not potentially feed on the same food resources as white-tailed deer, deer probably were not perceived as a threat or competition for food resources to the shore and wading bird species.

This information is helpful to wildlife managers and biologists who work in landscapes dominated by wetland vegetation types because white-tailed deer use does not seem to be impacting bird species use within wetland vegetation types. We did not see increased bird species richness when fewer deer were present. The only strong correlation we found was a positive trend and as deer numbers decreased so did bird species richness. However the results presented from this study can only be considered baseline data and very minimal counts. Because observing the wildlife was difficult after mid-June because of vegetation height, more wildlife could have been present and not accounted for. More in depth analysis on how different species are affected by the presence or absence of white-tailed deer would be needed to make

more definite conclusions if white-tailed deer influence wetland bird behavior when using wetland vegetation types.

MANAGEMENT IMPLICATIONS

The presence of white-tailed deer within wetland vegetation types does not seem to have a negative effect on the bird species composition using wetland vegetation types at SNWR. These results can be helpful for wetland managers and biologists. The implications of these results is that although white-tailed deer may be using the same wetland vegetation types as waterfowl, wading bird or shorebird species that are being managed for, white-tailed deer are not negatively impacting the use of the wetlands for those birds. Deer were mostly likely using wetlands as travel corridors to reach areas where more preferred food sources were available. Pusateri (2003) and Hiller (2007) also documented deer using wetland vegetation types for habitat within the summer and winter months. Deer may also be using some wetland vegetation types during the spring and summer for thermal cover, explaining why we saw them so frequently within different wetland types. Managers can then concentrate their management efforts into habitat requirements for the desired species. Managers and biologists do not have to take management efforts to keep white-tailed deer out of wetland vegetation types because deer use of those wetlands does not appear to be impacting bird use of the same wetlands.

Table 2.1. Age class of each management unit for 2011 and 2012 field seasons at Shiawassee National Wildlife Refuge. Age classes are defined as, early (<1yr since treatment), mid (1-2 years since treatment), and late (>2yrs since treatment). An X indicates the management unit was part of the age class.

Vegetation Type	Unit Name	2011			2012		
		Early	Mid	Late	Early	Mid	Late
Moist Soil							
	MSU 1			X	X*		X*
	MSU 2E			X			X
	MSU 2W	X				X	
	MSU 6			X	X		
Perennial Marsh							
	Pool 1A	X			X		
Lakeplain Prairie							
	SU 1	N/A	N/A	N/A	X		
	SU 3	N/A	N/A	N/A	X		

* MSU 1 underwent treatment mid-summer 2012, so for the first half of 2012 sampling period it was considered late age class and during the second half of 2012 sampling period it was considered early age class.

Table 2.2. Correlation coefficients between average number of white-tailed deer and average species richness for moist soil (MSU), perennial marsh (PM) and lakeplain prairie (LPP) vegetation types at Shiawassee National Wildlife Refuge, 2001 and 2012, for monthly (n=8) sampling and 15 day (n=4) sampling periods.

Wetland Vegetation Types	Correlation Coefficient	
	Monthly Sampling Period	15 day Sampling Period
MSU	0.45	0.02
PM	-0.10	-0.05
LPP	No value	No value

Table 2.3. Averages (standard errors) for moist soil (MSU), perennial marsh (PM), and lakeplain prairie (LPP) wetland vegetation types for number of deer and bird species richness for monthly sampling periods at Shiawassee National Wildlife Refuge, 2011 and 2012.

Start Date of Sampling Period	Average Deer per Vegetation Type			Average Species Richness per Vegetation Type		
	MSU	PM	LPP	MSU	PM	LPP
May 1	3.4 (1.1)	5.2 (1.4)	2.2 (0.7)	0.8 (0.9)	5.0 (1.0)	0.0 (0.0)
June 1	2.2 (1.2)	3.5 (1.7)	0.7 (0.1)	0.5 (0.4)	2.7 (0.6)	0.0 (0.0)
July 1	3.4 (2.4)	5.3 (2.1)	0.0 (0.0)	0.3 (0.3)	3.3 (0.6)	0.0 (0.0)
August 1	2.1 (2.0)	9.1 (3.1)	0.0 (0.0)	0.0 (0.0)	2.9 (0.5)	0.0 (0.0)
May 15	3.4 (1.1)	5.2 (1.4)	2.2 (0.7)	0.8 (0.2)	5.0 (1.0)	0.0 (0.0)
June 1	1.8 (0.4)	3.0 (1.1)	1.0 (0.1)	0.8 (0.2)	3.5 (1.0)	0.0 (0.0)
June 15	2.6 (0.5)	4.0 (1.4)	0.3 (0.0)	0.2 (0.1)	1.8 (0.4)	0.0 (0.0)
July 1	4.4 (1.3)	5.0 (1.9)	0.0 (0.0)	0.3 (0.2)	4.3 (0.8)	0.0 (0.0)
July 15	2.5 (0.6)	5.5 (1.2)	0.0 (0.0)	0.2 (0.1)	2.3 (0.8)	0.0 (0.0)
August 1	2.1 (0.6)	9.1 (3.1)	0.0 (0.0)	0.0 (0.0)	2.9 (0.5)	0.0 (0.0)

Table 2.4. Species composition of moist soil, perennial marsh, and lakeplain prairie wetland vegetation types at Shiawassee National Wildlife Refuge. E, M, and L indicates the species was observed at least one time in the early, mid or late successional age class of the moist soil units, PM indicates it was observed in the perennial marsh units, and LPP indicates it was seen in the lakeplain prairie units. An X indicates it was observed within all of the vegetation types and units.

Species		Monthly Sampling Period			
Common Name	Scientific Name	May	June	July	August
White-tailed Deer	<i>Odocoileus virginianus</i>	X	X	E,M, L,PM	E,M,L,P M
Blue Winged Teal	<i>Anas discors</i>	*PM	PM	PM	PM
Canada Goose	<i>Branta canadensis</i>	L, PM	L,PM	PM	PM
Dunlin	<i>Calidris alpina</i>	E, PM			
Great Blue Heron	<i>Ardea herodias</i>	E,M,L, PM	E,M,L ,PM	E,M, PM	L,PM
Great Egret	<i>Ardea alba</i>	E,M, PM	M,PM	E,PM	PM
Green Heron	<i>Butorides vicescens</i>	PM	PM	PM	PM
Herring Gull	<i>Larus argentatus</i>			PM	PM
Killdeer	<i>Charadrius vociferus</i>	E,M, PM	E,M, PM		
Lesser Yellowlegs	<i>Tringa flavipes</i>	PM			
Mallard	<i>Anas platyrhynchos</i>	E,M,L, PM	E,PM	L,PM	L,PM
Northern Shoveler	<i>Anas clypeata</i>	E			
Pied-billed Grebe	<i>Podilymbus podiceps</i>	PM	PM	PM	PM
Sandhill Crane	<i>Grus canadensis</i>	E,M	E,M,L	M	

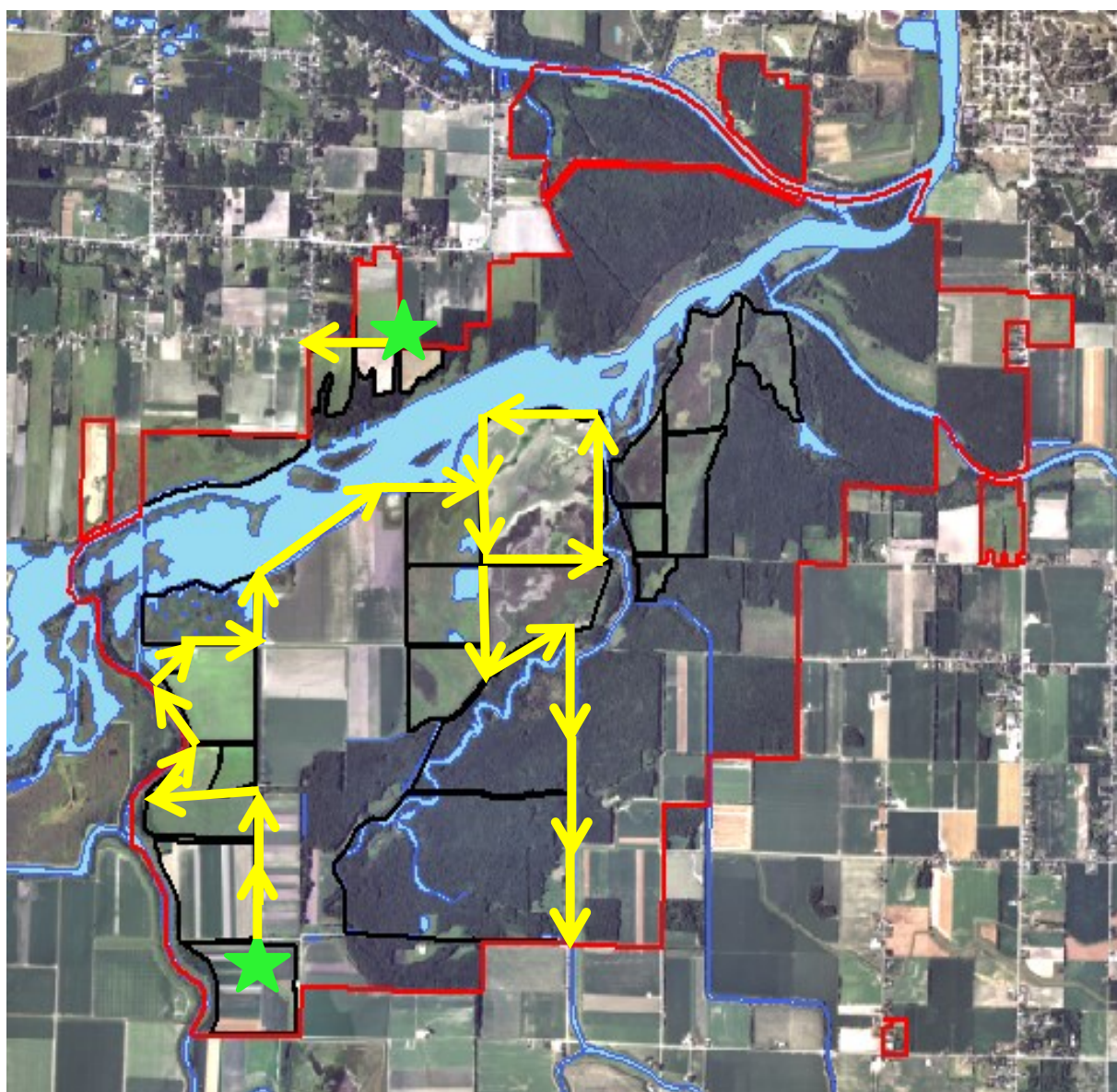
*No wetland bird species were observed during any sampling periods within the lakeplain prairie vegetation types

Table 2.5. Average number of white-tailed deer and average bird species richness (standard errors) for early (<1 year since treatment), mid (1-2 years since treatment), and late (>2 years since treatment) age classes of the moist soil vegetation type at Shiawassee National Wildlife Refuge, 2011 and 2012.

Start Date of Sampling Period	Average Deer per Age Class			Average Species Richness per Age Class		
	Early	Mid	Late	Early	Mid	Late
May 1	4.0 (1.6)	0.6 (0.3)	0.0 (0.0)	2.2 (0.6)	0.3 (0.1)	0.6 (0.3)
June 1	2.1 (1.0)	1.2 (0.6)	5.1 (1.6)	0.8 (0.4)	1.2 (0.6)	0.6 (0.2)
July 1	2.1 (0.9)	1.2 (0.8)	4.3 (1.6)	0.0 (0.3)	0.0 (0.0)	0.3 (0.1)
August 1	1.2 (1.0)	0.7 (0.7)	5.5 (2.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
May 15	4.0 (1.6)	0.6 (0.3)	0.0 (0.0)	2.2 (0.6)	0.3 (0.1)	0.6 (0.3)
June 1	1.1 (1.0)	1.0 (0.4)	8.3 (2.9)	1.3 (0.3)	2.0 (1.2)	0.9 (0.3)
June 15	3.1 (1.1)	1.4 (0.8)	1.8 (0.5)	0.3 (0.2)	0.4 (0.2)	0.3 (0.1)
July 1	2.4 (1.6)	1.7 (0.9)	3.5 (1.0)	0.0 (0.0)	0.0 (0.0)	0.5 (0.1)
July 15	1.8 (0.6)	0.7 (0.7)	5.0 (1.9)	0.0 (0.0)	0.0 (0.0)	0.2 (0.1)
August 1	1.2 (1.0)	0.7 (0.7)	5.5 (2.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

Table 2.6. Correlation coefficients for average number of white-tailed deer and bird species richness for early (<1 year since treatment), mid (1-2 years since treatment), and late (>2 years since treatment) age classes of the moist soil vegetation type on monthly (n=8) and 15 day (n=4) sampling periods at Shiawassee National Wildlife Refuge, 2011 and 2012.

Age Class	Correlation Coefficient	
	Monthly Sampling Period	15 day Sampling Period
Early	0.94	0.50
Mid	0.49	0.03
Late	-0.29	-0.21



Legend

- SNWR Boundary
- Impoundment Boundary
- ★ Alternate Starting Points of Survey
- ➔ Survey Route

Figure 2.1. Driving survey routes at Shiawassee National Wildlife Refuge (SNWR) for sampling bird species richness and deer use of wetland vegetation types during 2011 and 2012. Arrows indicate driving route and green stars indicate starting/ending point of the survey.

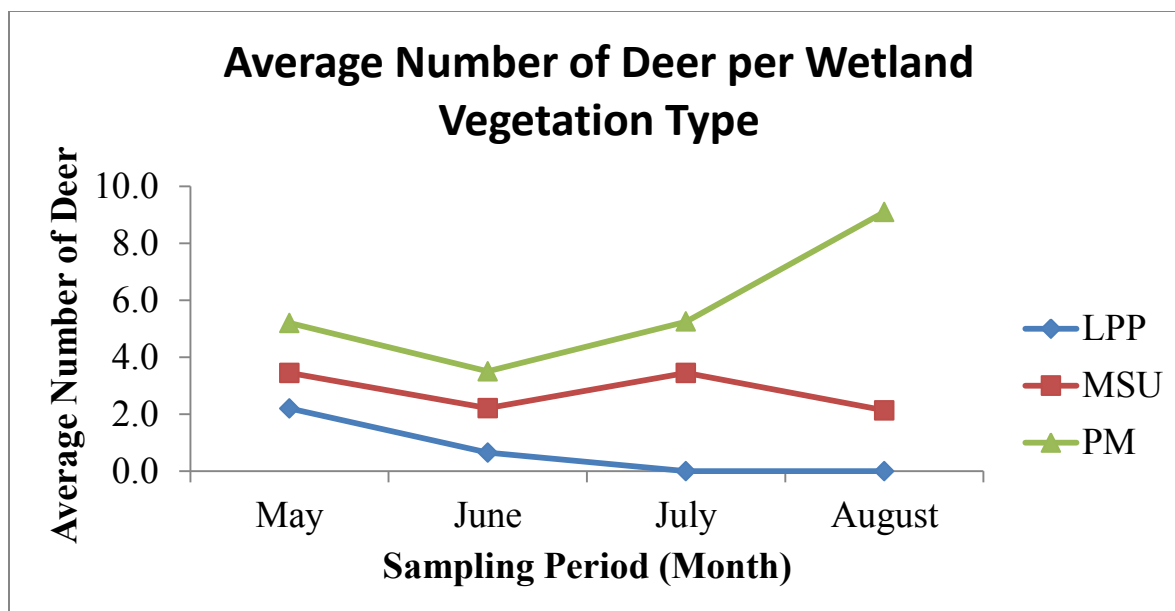


Figure 2.2. Average number of white-tailed deer present in moist soil (MSU), perennial marsh (PM), and lakeplain prairie (LPP) wetland vegetation types over time on a monthly basis at Shiawassee National Wildlife Refuge, 2011 and 2012.

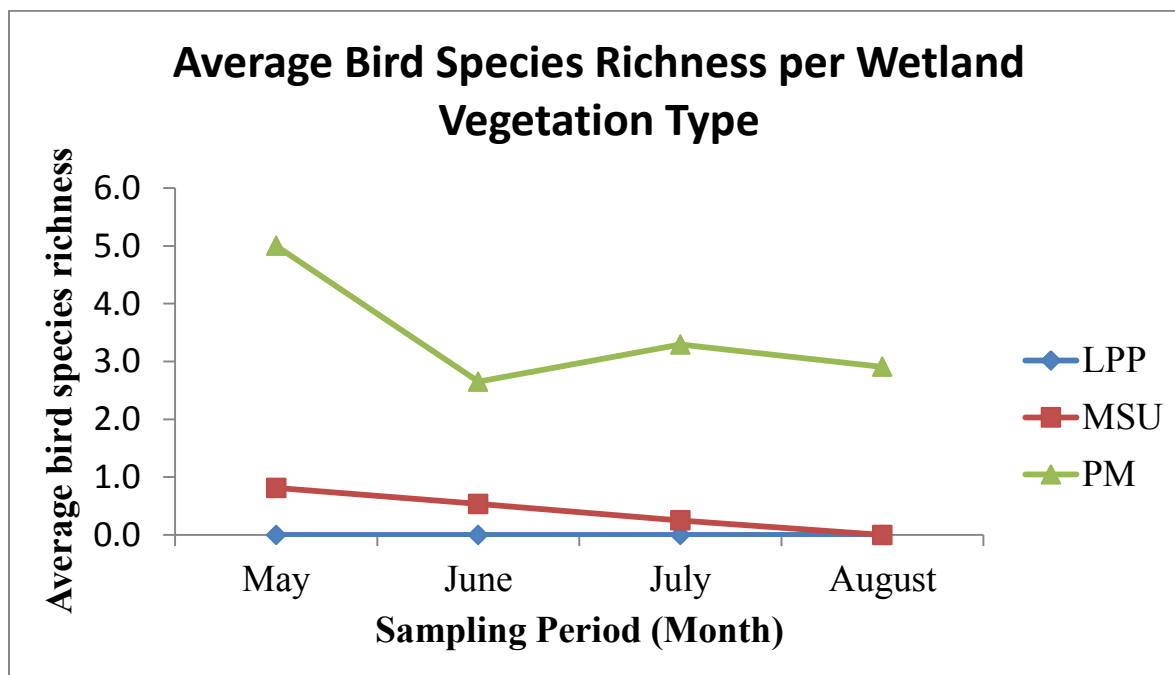


Figure 2.3. Average bird species richness present in moist soil (MSU), perennial marsh (PM), and lakeplain prairie (LPP) wetland vegetation types over time on a monthly average at Shiawassee National Wildlife Refuge, 2011 and 2012.

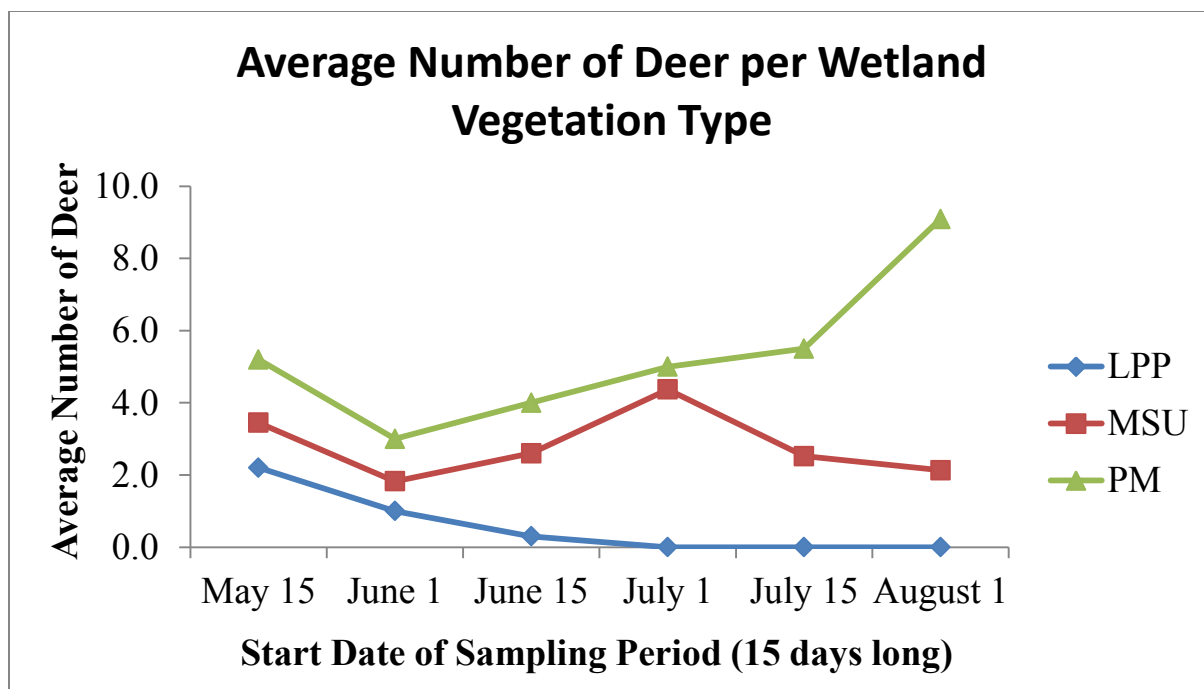


Figure 2.4. Average number of white-tailed deer present in moist soil (MSU), perennial marsh (PM), and lakeplain prairie (LPP) wetland vegetation types over time on a 15 day average at Shiawassee National Wildlife Refuge, 2011 and 2012.

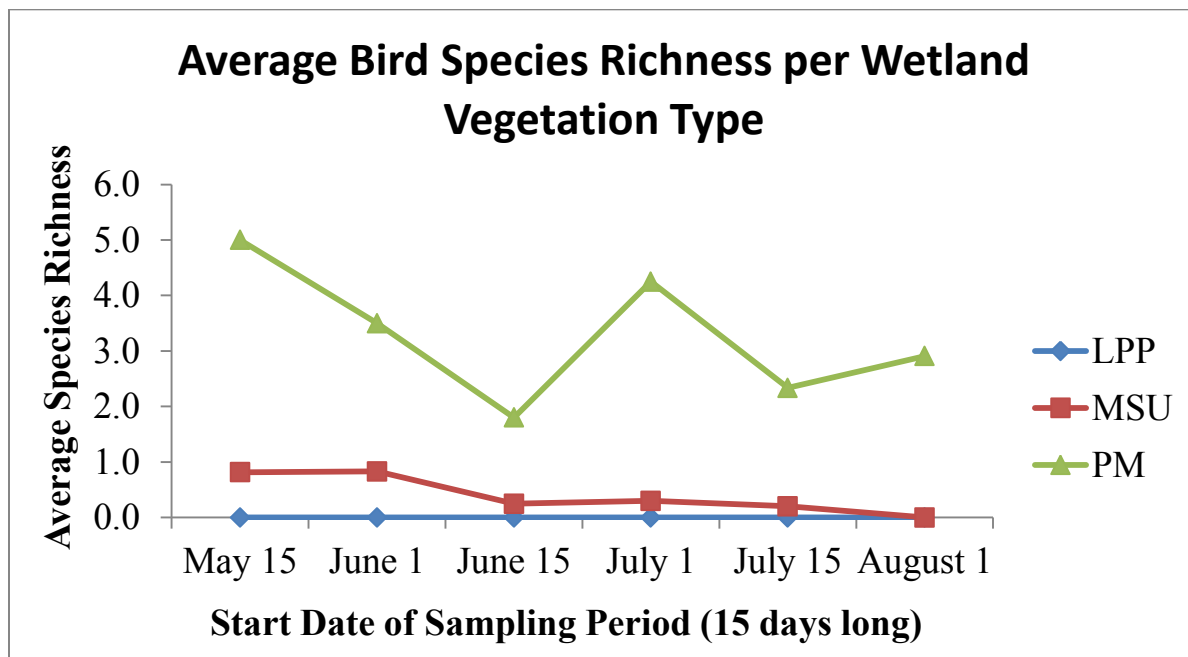


Figure 2.5. Average bird species richness present in moist soil (MSU), perennial marsh (PM), and lakeplain prairie (LPP) wetland vegetation types over time on a 15 day average at Shiawassee National Wildlife Refuge, 2011 and 2012.

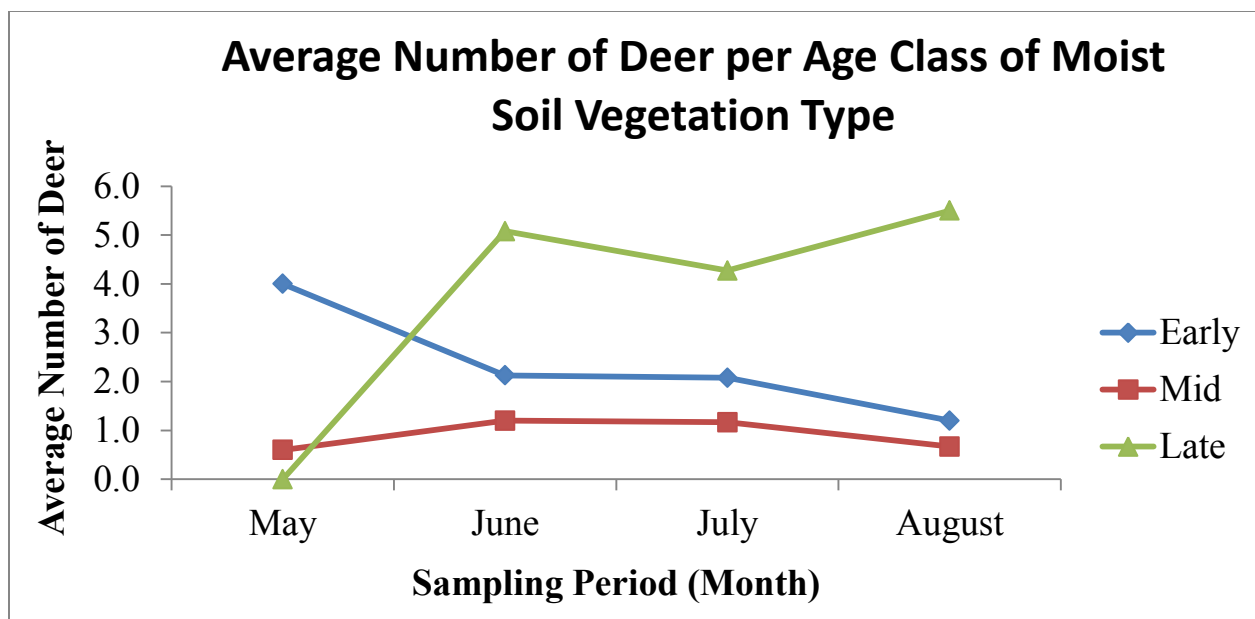


Figure 2.6. Average number of white-tailed deer present in the moist soil vegetation type per age class; early (<1 year since treatment), mid (1-2 years since treatment), and late (>2 years since treatment) over monthly sampling periods at Shiawassee National Wildlife Refuge, 2011 and 2012.

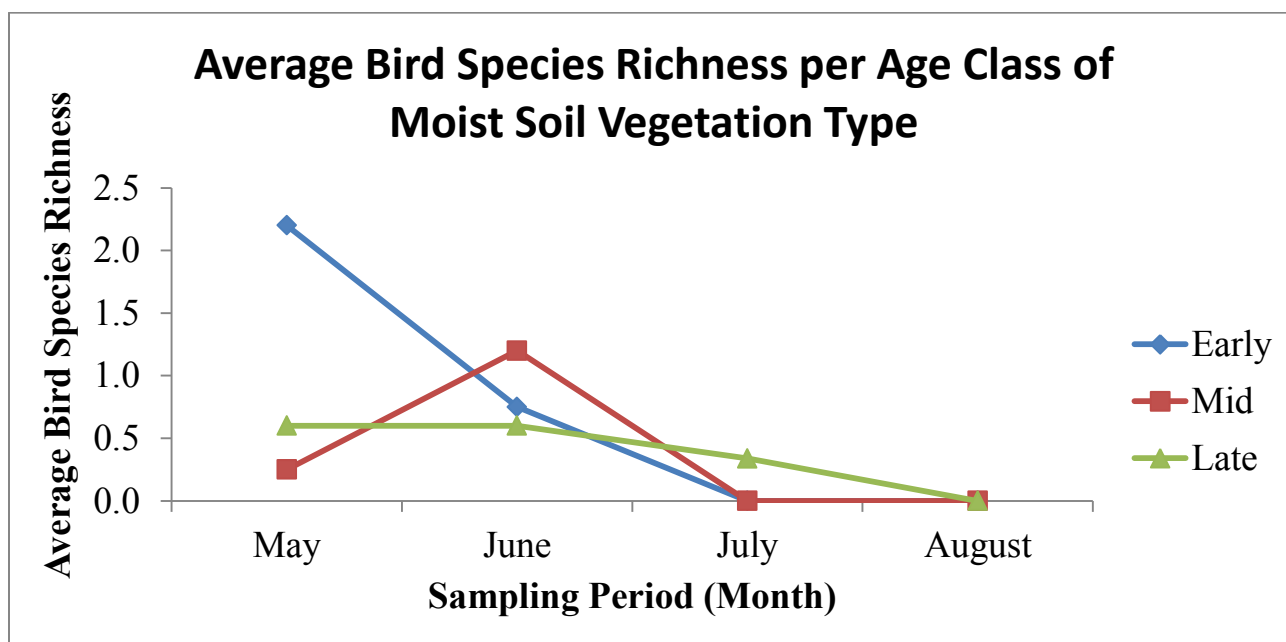


Figure 2.7. Average bird species richness in the moist soil vegetation type per age class; early (<1 year since treatment), mid (1-2 years since treatment), and late (>2 years since treatment) over monthly sampling periods at Shiawassee National Wildlife Refuge, 2011 and 2012.

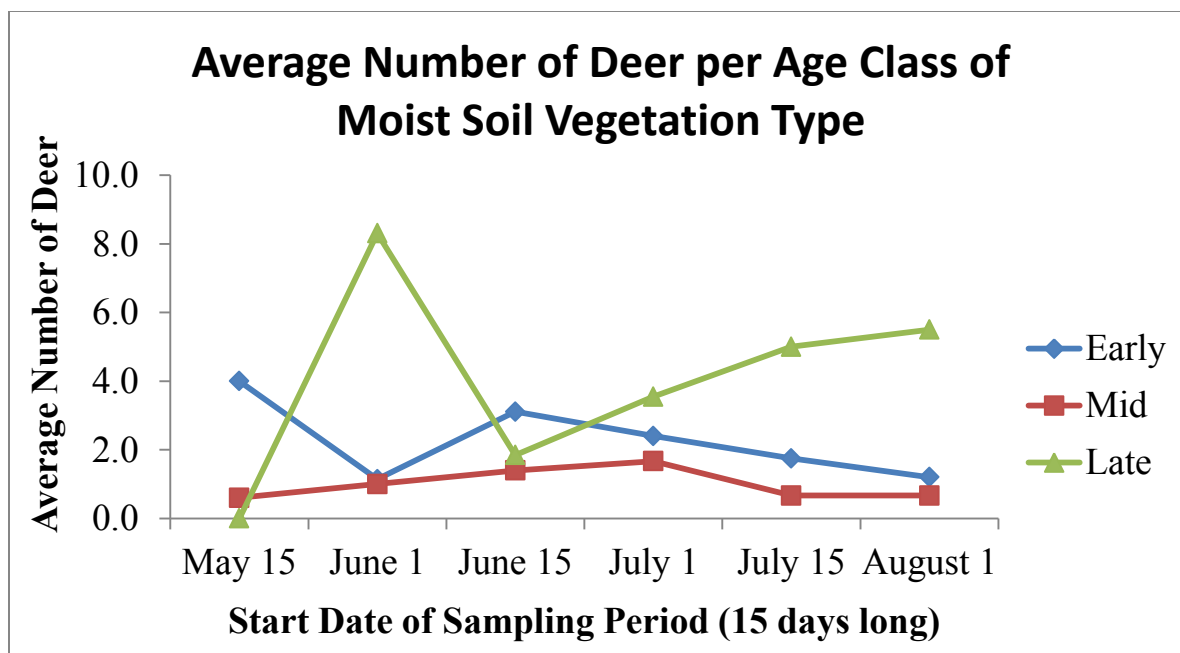


Figure 2.8. Average number of white-tailed deer present in the moist soil vegetation type per age class; early (<1 year since treatment), mid (1-2 years since treatment), and late (>2 years since treatment) over monthly 15 day sampling periods at Shiawassee National Wildlife Refuge, 2011 and 2012.

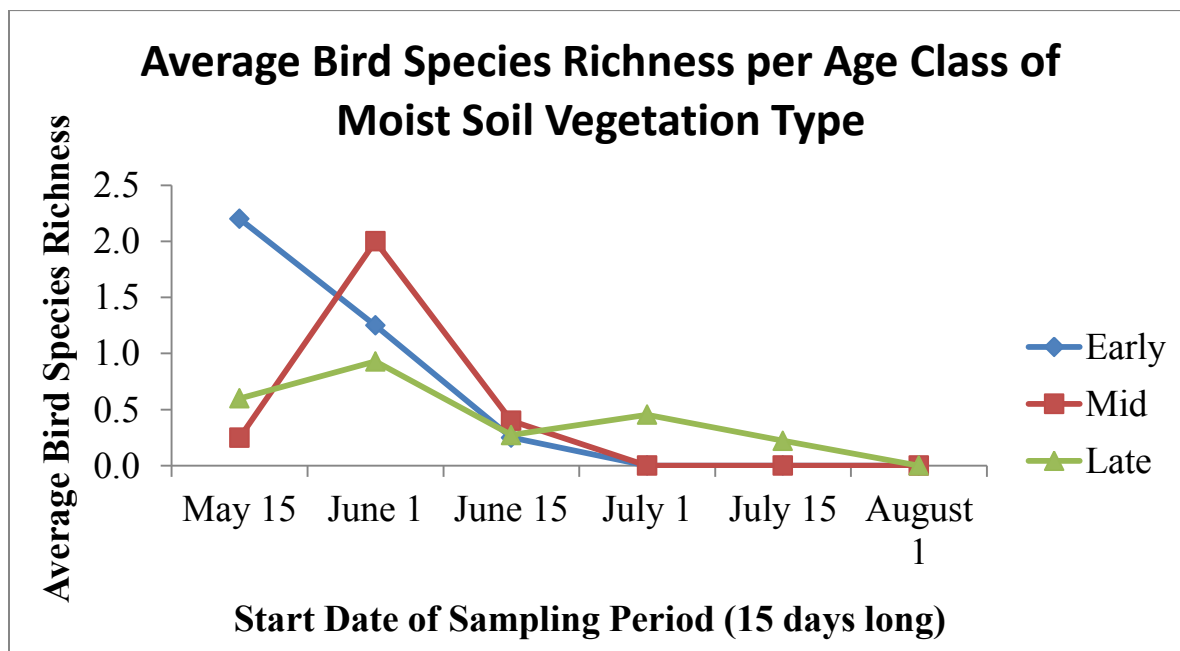


Figure 2.9. Average bird species richness in the moist soil vegetation type per age class; early (<1 year since treatment), mid (1-2 years since treatment), and late (>2 years since treatment) over 15 day sampling periods at Shiawassee National Wildlife Refuge, 2011 and 2012.

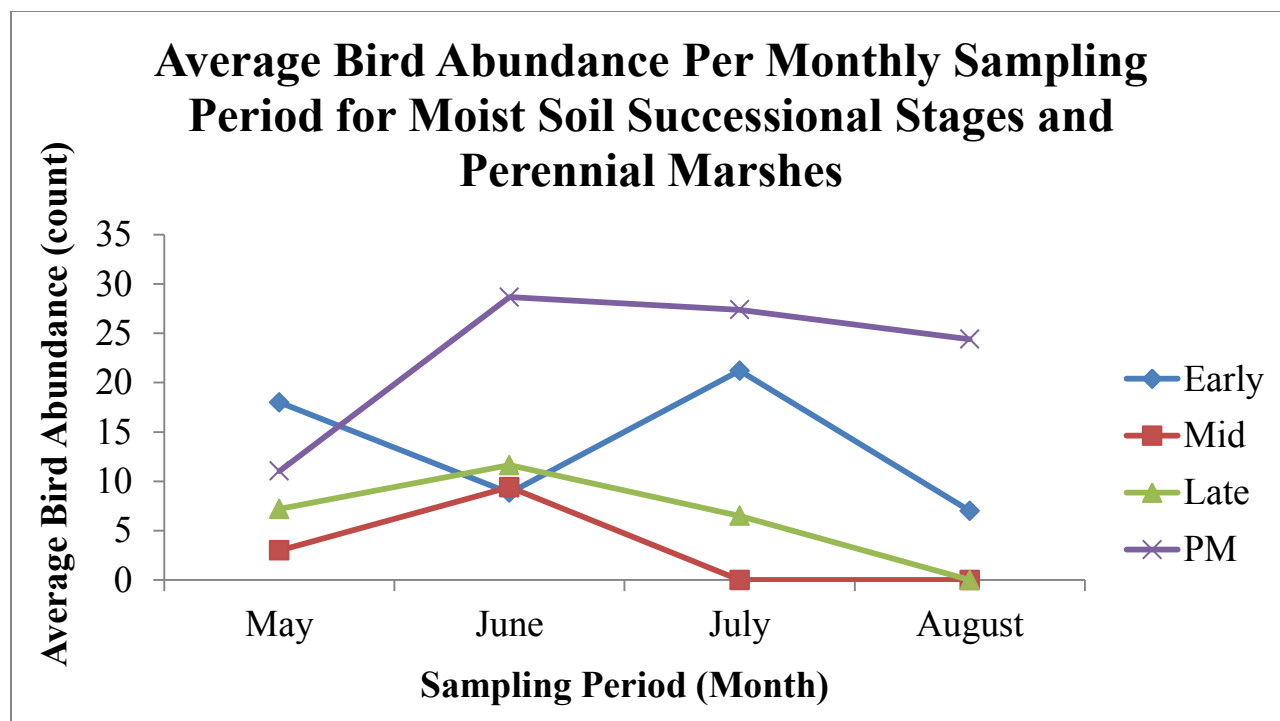


Figure 2.10. Average bird abundance counts for perennial marsh (PM) and moist soil vegetation type successional stages; early (>1 year since treatment), mid (1-2 years since treatment), and late (<1 year since treatment).

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CHAPTER 3

Effects of white-tailed deer herbivory within wetland vegetation types on a landscape dominated by wetlands

INTRODUCTION

Over the past few decades white-tailed deer densities (*Odocoileus virginianus*) have increased to levels well above the historic range of variability (Rooney 2001). Pre-settlement deer density estimates in North America were found about 3.1 to 4.2 deer per km⁻² (Rooney 2001) while common densities of 10 deer/ km² frequently occur in the Midwest (Rooney and Waller 2003, Kraft et al 2004). Historical removal of native predators, such as the grey wolf (*Canis lupus*) and cougar (*Felis concolor*), changes in hunting regulations, and habitat modification have all also contributed to the expansion of deer populations throughout their range (Rooney 2001). In recent decades, logging of late successional forests allowed for substantial regeneration of new growth and pioneer species which are preferred food for white-tailed deer (Russell et al. 2004, Rooney 2001, Waller and Alverson 1997).

High densities of deer can be a challenge for natural resource managers because deer can act as keystone herbivores (Waller and Alverson 1997, Rooney 2001). The structural integrity of forest vegetation types can be modified or compromised in cases of high deer densities and intense herbivory. Vertical structure is an important deer habitat component because it directly influences the quantity and quality of the habitat and can influence how wildlife selects habitat (Haukos et al. 1998, Felix et al. 2007). Important understory components such as saplings, seedlings, herbs and shrubs are prone to heavy browsing pressure and in some instances can be completely eliminated (Rooney 2001).

Deer herbivory can also cause a shift from one vegetation type to another. In severe cases, instances where deer herbivory has negatively affected plant communities by reducing the structure, composition or productivity, deer have set back succession by consuming the entire understory leaving only ferns and less palatable plants: American beech (*Fagus grandifolia*) and

hay scented fern (*Dennstaedtia punctilobula*) (Rooney 2001). Recruitment and regeneration failure of preferred tree species of white-tailed deer is also commonly seen. Eastern hemlock (*Tsuga Canadensis*) and oak (*Quercus spp.*) forests have undergone compositional shifts due to browsing pressure from white-tailed deer with seedling regeneration showing a negative linear correlation with browsing pressure (Rooney and Waller 2003). Deer herbivory can also limit seedling growth, and negative correlations have been observed between the number of seedlings present in a landscape and deer abundance (Waller and Alversons 1997). These trends have also been seen in northern white-cedar (*Thuja occidentalis*) and yellow birch (*Betula alleghaniensis*), which are also nutritionally important and favored food species for white-tailed deer (Rooney and Waller 2003, Barnes and Wagner 2008).

When deer herbivory changes the structure and composition of ecosystems, productivity is also jeopardized. The absolute and relative abundance of woody and herbaceous species has been negatively correlated with deer herbivory (Waller and Alverson 1997). In areas protected from deer herbivory it is not uncommon to see increases in the number of leaves per plant, plant height, numbers and sizes of fruits, flowers, and seeds, and the proportion of flowering and fruiting individuals (Kraft et al. 2004, Urbanek et al. 2012). Total forest biomass production can also be reduced by deer herbivory because seedling growth at ground cover level can be stunted (Kraft et al 2004). Impacts of deer and elk herbivory may have a time limit and do not necessarily affect forest structure over the long term in the same manner as deer herbivory does over the short term (Raymer 2000).

White-tailed deer may use other vegetation types besides forests to fulfill their life requisites. White-tailed deer to use a variety of wetland vegetation types for feeding, and hiding

cover (Pusateri 2003, Hiller 2007). If deer herbivory can negatively impact forest vegetation types then it can be surmised they can have similar effects on other vegetation types.

A knowledge gap exists on how deer herbivory impacts wetland vegetation types. This is a concern to wetland managers and National Wildlife Refuge managers because wetlands are often not managed for white-tailed deer, but are managed for resident and migratory waterfowl (USFWS 2010). Understanding how deer herbivory impacts wetland vegetation types will help managers plan and implement more effective management strategies in landscapes dominated by wetlands. The objective of this study was to quantify white-tailed deer herbivory within a landscape dominated by wetlands.

STUDY AREA

Our study area was located at SNWR in the eastern lower peninsula of Michigan in Saginaw County (USFWS 2010, USDA 1997). SNWR sits on many different commonly flooded soils such as sandy-loams, Misteuaysilty clays, fluvaquents and mucks along with some soils that are infrequently flooded; sloan silt loam and sloan-ceresco complexes (USDA 2009). The refuge is 3,845 ha and 75% of it is composed bottom-land hardwood forests while the remaining 25% is rivers, perennial marshes, moist soil units, lakeplain prairies, and crop lands (USFWS 2010). The adjacent landscape was composed of wetland vegetation types, agriculture fields, and deciduous forest vegetation types. SNWR experiences temperate climate conditions with an average yearly temperature of 8.3°C, temperatures ranging from 8.0°C to 32.2°C during the growing season and highs and lows throughout the year observed in August and January respectively (National Weather Service 2007).

SNWR is an important stopover site for over 270 species of migratory birds annually and is located on some of Michigan's most productive wetlands. Thousands of birds have been

observed at the refuge during fall and spring migrations as well as many resident bird species (USFWS 2010). The only current management strategies being conducted are water manipulations of the perennial marshes and moist soil units accompanied by spraying, mowing and disking moist soil units as needed to set back succession (Gray et al. 1999, Steven Kahl, SNWR manager, Eric Dunton, SNWR wildlife biologist, personal correspondence).

SNWR, perhaps like other national wildlife refuges, has experienced issues related to high deer densities and deer herbivory including, complaints from nearby farmers about agricultural damage from white-tailed deer, high doe:buck ratios, low fawn weights and extensive damage to forests. In an effort to combat these issues, SNWR has reduced antlerless deer densities by implementing a structured hunting season on the refuge and issuing harvesting permits on a yearly basis since the early 1980's (Steven Kahl, SNWR manager, Eric Dunton, SNWR wildlife biologist, personal correspondence).

METHODS

To quantify white-tailed deer herbivory within moist soil, perennial marsh, lakeplain prairie, and bottomland hardwood forest vegetation types we selected random sites to construct exclosures in each vegetation type and paired them with areas open to herbivory to assess browsing effects from May-August 2011 and 2012. We used 4 moist soil units, 2 perennial marsh units, 2 lakeplain prairie units, and 3 bottomland hardwood forest units. Before exclosure construction each management unit within moist soil and perennial marsh vegetation types were stratified into core (>90m from the edge of the unit) and edge (<90m from the edge of the unit). We used this stratification because research by Williamson and Hirth (1985), Braun (1996), Vercauteren and Hygnstrom (1998), and Stewart et al. (2006) suggest deer use the edge of fields for feeding more heavily than the core area. The size of the lakeplain prairie vegetation type management units did not allow stratification into core and edge. Bottomland hardwood forests

were not stratified into core and edge because previous research did not indicate deer would use the edge of these vegetation types more than the core. A minimum of 6 exclosures and paired open areas were placed into each unit, equal within the core and edge stratification. In units larger than 13ha we used 1 exclosure per 2.15ha, again with equal numbers within the core and edge stratification. Exclosures within the bottomland hardwood forest vegetation type were 20m X 20m X 2.4m according to other researchers who investigated the influence of large herbivores on forest communities (Campa et al. 1992) and 3 X 3m in the moist soil, perennial marsh and lakeplain prairie vegetation types (Rodríguez –Pérez and Green 2006). Paired open area sites were placed randomly 10m away from each exclosure in an effort to reduce bias if deer are attracted to or deterred from exclosures (Braun 1996).

Bottomland hardwood forest exclosures were constructed out of wire mesh farm fencing with 5.0 X 7.5cm openings. These exclosures were constructed to start a long term monitoring study on how deer herbivory affects bottomland hardwood forests. Exact locations of each exclosure and paired open area and vegetation sampling data sheets for continued data collection are in Appendix A. Moist soil, perennial marsh, and lakeplain prairie exclosures were constructed using 4 corner t-post polymesh fencing with 1.87 X 1.87cm openings. These exclosures were only 1.52m high because we assumed the size of the exclosures (3m X 3m) would not encourage deer jumping into them. During the study deer were never observed within these exclosures. There were also no tops placed on these exclosures to allow bird use and fencing was approximately 0.22m above the ground to allow for small mammals to enter the exclosures to ensure we were only isolating deer herbivory.

We evaluated horizontal cover in every exclosure and paired open area in every management unit using a profile board in late July of 2011 and 2012. To quantify horizontal

cover we used 5 categories of cover when making our ocular estimates; 0-20%, 20-40%, 40-60%, 60-80%, and 80-100%. We quantified horizontal cover with the moist soil, perennial marsh, and lakeplain prairie vegetation types for <1.0m height strata. Within the bottomland hardwood forest vegetation type we quantified horizontal cover within 0-0.5m, 0.5-1.0m and >1.0m height strata. A minimum of 3 measurements were taken at each exclosure and open area. Measurements were averaged per management unit and per vegetation type.

Vertical cover was quantified using the line intercept method during late July of 2011 and 2012 (Canfield 1941). Within moist soil, perennial marsh, and lakeplain prairie vegetation types line intercepts were 3m in length and vertical cover was quantified for all vegetation <1.0m in height. Within the bottomland hardwood forest vegetation type, we assessed vertical cover within 4 different height strata with a 10 m transect; <1.0m, 1.0-2.0, and >2.0m. We took 3 vertical cover measurements in each exclosure and paired open area for all vegetation types and then averaged these measurements. Measurements were then averaged on a per management unit and vegetation type basis.

We evaluated the plant species richness of moist soil, perennial marsh, lakeplain prairie, and bottomland hardwood forest vegetation types during late July of 2011 and 2012. Within the moist soil, perennial marsh, and lakeplain prairie vegetation types the number of species present in a 0.5m² randomly placed plots within exclosures and open areas was recorded (Atkinson et al. 2010). Within the bottomland hardwood forests we took overstory species richness measurements within 20 X 20m plots.

We measured total above ground and seed biomass of moist soil, perennial marsh, and lakeplain prairie vegetation types within all exclosures and open areas during mid-August of 2011 and 2012. Vegetation was clipped at ground level within a 0.5m² area placed randomly

within the enclosure and paired open area. Vegetation was separated by species and then dried at 100°C to a constant dry weight before being massed (Atkinson et al. 2010). Total biomass was massed with seed heads still attached to plants and seed heads were removed and massed separately to obtain seed biomass measurements.

We also visually documented the structure, composition, and productivity of each enclosure and paired open area of moist soil, perennial marsh and lakeplain prairie vegetation types by photographing each enclosure on a monthly basis with the first photo being taken when the enclosures were constructed and the last photo taken when the enclosures were taken down. Photos were taken from the same direction and at times during the day when there was the same amount of light to reduce potential mirages from light or distance. These photos are archived at Michigan State University with Dr. Henry Campa, III and at SNWR.

We analyzed plant composition, structure, and productivity data by first looking at the averages of each vegetation type and making 3 comparisons within each vegetation type. We compared all enclosures to all open areas, core enclosures to core open areas, and edge enclosures to edge open areas. Then we analyzed each management unit or impoundment individually within the vegetation types doing the same 3 comparisons for all variables. We used two-tailed t-tests to make all comparisons ($\alpha=0.10$) between enclosures and paired areas open to foraging.

RESULTS

Moist Soil Vegetation Type

Within the moist soil vegetation type there were no significant differences for the average horizontal cover between all enclosures (80-100%) and all open areas (80-100%), between all

core exclosures (80-100%) and all core open areas (80-100%), nor between all edge exclosures (80-100%) and all edge open areas (80-100%) ($P>0.10$, $\alpha=0.10$) (Table 3.1). We found no significant differences between any of the management units when comparing all exclosures to all open areas, core exclosures to core open areas, and edge exclosures to edge open areas because the mean value for horizontal cover was 80-100% for every moist soil management unit and every category.

There were no significant differences in vertical cover for moist soil units between all exclosures (96.6%) compared to all open areas (96.9%), core exclosures (97.2%) compared to core open areas (97.2%), or when edge exclosures (96.6%) were compared to edge open areas (96.1%) ($P>0.10$, $\alpha=0.10$) (Table 3.2). We found no significant differences among the means within each moist soil management unit; MSU1, MSU 2E, MSU 2W, MSU 6. There are no significant differences within MSU 1 between all exclosures (95.8%) and all open areas (95.8%), between core exclosures (93.3%) and core open areas (93.3%), and between edge exclosures (98.3%) and edge open areas (98.3%) ($P>0.1$, $\alpha=0.10$) (Table 3.2). Within MSU 2E there were no significant differences in vertical cover among all exclosures (95.0%) compared to all open areas (94.2%), core exclosures (98.3%) to core open areas (98.3%), and edge exclosures (91.7%) to edge open areas (90.0%) ($P>0.1$, $\alpha=0.10$) (Table 3.2). Within MSU 2W, we found no significant differences among the means when comparing all exclosures to all open areas, core exclosures to core open areas, and edge exclosures to edge open areas because all means were exactly the same at 100% ($P>0.1$, $\alpha=0.10$) (Table 3.2). Looking at MSU 6 we found no significant differences between all exclosures (98.7%) and all open areas (98.3%), core exclosures (100.0%) to core open areas (100.0%), and edge exclosures (97.4%) to edge open areas (96.6%) ($P>0.1$, $\alpha=0.10$) (Table 3.2).

Species richness was analyzed making the same 3 comparisons between core and edge exclosures, among each moist soil management unit and as a whole for the moist soil vegetation type. Within the moist soil vegetation type there was no significant difference between species richness when comparing all exclosures (5.7) to all open areas (5.3), core exclosures (5.9) to core open areas (5.9), and edge exclosures (5.0), to edge open areas (5.3) ($P>0.1$, $\alpha=0.10$) (Table 3.3). There were no significant differences between average species richness within MSU 1 when comparing between all exclosures (6.6) to all open areas (6.0), core exclosures (6.0) to core open areas (6.3), and edge exclosures (6.0) to edge open areas (7.0) ($P>0.1$, $\alpha=0.10$) (Table 3.3). In addition, there were no significant differences between average species richness with MSU 2E, MSU 2W and MSU 6, respectively when comparing between all exclosures (5.5, 5.3, and 5.5) to all open areas (5.1, 5.3, and 5.1), core exclosures (5.3, 7.2, and 5.3) to core open areas (5.3, 6.2, and 6.0), and edge exclosures (5.6, 3.5, and 5.0) to edge open areas (5.0, 4.3, and 4.8) ($P>0.1$, $\alpha=0.10$) (Table 3.3).

There were no significant differences in total above ground biomass among the moist soil vegetation type when comparing all exclosures (160.0kg/ha) to all open areas (178.7kg/ha), all core exclosures (157.1kg/ha) to all core open areas (183.3kg/ha), and all edge exclosures (163.3kg/ha) to all edge open areas (174.1kg/ha) ($P>0.1$, $\alpha=0.10$) (Table 3.4). When analyzing MSU 1 individually, we found no significant differences between above ground biomass between all exclosures (99.1kg/ha) to all open area (141.8kg/ha), core exclosures (138.4kg/ha) to core open areas (102.0kg/ha), and edge exclosures (145.0kg/ha) to edge open areas (96.4kg/ha) ($P>0.1$, $\alpha=0.10$) (Table 3.4). Within MSU 2E we found no significant differences when comparing all exclosures (143.3kg/ha) to all open areas (152.2kg/ha), core exclosures (140.7kg/ha) to core open areas (164.2kg/ha), and edge exclosures (146.2kg/ha) to edge open

areas (38.5kg/ha) ($P>0.1$, $\alpha=0.10$) (Table 3.4). Within MSU 2W we found no significant difference when comparing all exclosures (159.8kg/ha) to all open areas (169.0kg/ha), core exclosures (148.4kg/ha) to core open areas (164.0kg/ha), and edge exclosures (173.1kg/ha) to edge open areas (173.1kg/ha) ($P>0.1$, $\alpha=0.10$) (Table 3.4). Within MSU 6 we found no significant differences in biomass between all exclosures (201.0kg/ha) to all open areas (227.6kg/ha), core exclosures (199.7kg/ha) to core open areas (236.1kg/ha), and edge exclosures (202.6kg/ha) to edge open areas (218.1kg/ha) ($P>0.1$, $\alpha=0.10$) (Table 3.4).

No significant differences ($P>0.10$, $\alpha=0.10$) in seed biomass occurred on moist soil vegetation types between all exclosures (39.4kg/ha) and all open areas (35.9kg/ha), all core exclosures (33.8kg/ha) and all core open areas (39.5kg/ha), and all edge exclosures (49.2kg/ha) and all edge open areas (31.8kg/ha) (Table 3.5). Similarly, no significant differences in seed biomass production occurred on MSU 1 between all exclosures (12.7kg/ha) to all open areas (24.2kg/ha), core exclosures (8.6kg/ha) to core open areas (14.8kg/ha), and edge exclosures (33.5kg/ha) to edge open areas (15.0kg/ha) (Table 3.5). Within MSU 2E we found no significant differences between the mean seed biomass production of all exclosures (6.8kg/ha) and all open areas (11.2kg/ha), core exclosures (5.3kg/ha) and core open areas (11.4kg/ha), and edge exclosures (9.7kg/ha) and edge open areas (11.3kg/ha) (Table 3.5). Within MSU 2W we found no significant differences between the means of seed biomass when comparing all exclosures (33.3kg/ha) to all open areas (31.5kg/ha), core exclosures (21.5kg/ha) to core open areas (35.1kg/ha), and edge exclosures (49.9kg/ha) to edge open areas (28.6kg/ha) (Table 3.5). Within MSU 6 we found no significant differences when comparing mean seed biomass of all exclosures (75.6kg/ha) to all open areas (58.0kg/ha) and core exclosures (63.3kg/ha) to core open areas (65.55kg/ha). Moist soil unit 6 did have significantly less ($P<0.10$, $\alpha=0.1$) seed biomass

production in the open areas (46.8kg/ha) in the edge region than within the exclosures (133.4kg/ha) in the edges (Table 3.5).

Perennial Marsh Vegetation Type

There were no significant differences in the percent horizontal cover of the perennial marsh vegetation type when comparing all exclosures (60-80%) to all open areas (60-80%), all core exclosures (20-40%) to all core open areas (20-40%), and all edge exclosures (80-100%) to all edge open areas (80-100%) ($P>0.1$, $\alpha=0.10$) (Table 3.6). Similarly, there were no significant differences in horizontal cover within each individual management unit, Butch's Marsh or Pool 1A ($P>0.1$, $\alpha=0.10$) (Table 3.6).

There were no significant differences ($P>0.10$) in the mean percent vertical cover within the perennial marsh vegetation type between all exclosures (54.5%) to all open areas (55.8%), all core exclosures (30.8%) to all core open areas (34.1%), and all edge exclosures (78.3%) to all edge open areas (77.4%) ($P>0.1$, $\alpha=0.10$) (Table 3.7). Within Butch's Marsh, we found no significant differences in the mean percent vertical cover within all exclosures (64.1%) compared to all open areas (64.1%), core exclosures (36.6%) to core open areas (36.6%), and edge exclosures (91.6%) to edge open areas (91.6%) ($P>0.1$, $\alpha=0.10$) (Table 3.7). Similarly, within Pool 1A, there were no significant differences ($P>0.10$) in mean percent vertical cover between all exclosures (45.0%) to all open areas (47.6%), core exclosures (25.0%) to core open areas (31.8%), and edge exclosures (65.0%) to edge open areas (63.3%) (Table 3.7).

When comparing mean species richness within the perennial marsh vegetation type we found no significant differences between all exclosures (3.6) and all open areas (3.6), all core exclosures (4.0) and all core open areas (4.0), or all edge exclosures (3.3) and all edge open areas

(3.3) ($P>0.1$, $\alpha=0.10$) (Table 3.8). Looking at Butch's Marsh individually we found no significant differences in mean species richness between all exclosures (2.0) and all open areas (1.6), core exclosures (2.5) and core open areas (1.5), and edge exclosures (1.6) and edge open areas (1.6) ($P>0.1$, $\alpha=0.10$) (Table 3.8). Looking at just Pool 1A we found no significant differences between all exclosures (4.5) and all open areas (4.7), core exclosures (4.6) and core open areas (5.0), and edge exclosures (4.4) and edge open areas (4.4) ($P>0.1$, $\alpha=0.10$) (Table 3.8).

When comparing mean total above ground biomass production we found no significant differences with the perennial marsh vegetation type when comparing all exclosures (296.0kg/ha) to all open areas (313.2kg/ha), all core exclosures (249.7kg/ha) to all core open areas (238.9kg/ha), and all edge exclosures (346.0kg/ha) to all edge open areas (399.3kg/ha) ($P>0.1$, $\alpha=0.10$) (Table 3.9). Looking at Butch's Marsh individually we found no significant differences when comparing the means of total above ground biomass of all exclosures (535.1kg/ha) to all open areas (663.6kg/ha), core exclosures (387.0kg/ha) to core open areas (571.5kg/ha), and edge exclosures (683.6kg/ha) to edge open areas (737.3kg/ha) ($P>0.1$, $\alpha=0.10$) (Table 3.9). Within Pool 1A we found no significant differences between the means of the total above ground biomass when comparing all exclosures (247.1kg/ha) to all open areas (243.1kg/ha), core exclosures (219.8kg/ha) to core open areas (185.7kg/ha), and edge exclosures (265.3kg/ha) to edge open areas (314.8kg/ha) ($P>0.1$, $\alpha=0.10$) (Table 3.9).

When comparing the means of seed biomass production within the perennial marsh vegetation type, Pool 1A was the only management unit which produced any seed mass. We found no significant differences between mean seed mass production when comparing all exclosures (25.0kg/ha) to all open areas (29.3kg/ha), core exclosures (12.7kg/ha) to core

exclosures (25.2kg/ha), and edge exclosures (36.3kg/ha) to edge open areas (32.7kg/ha) within Pool 1A ($P>0.1$, $\alpha=0.10$) (Table 3.10).

Lakeplain Prairie Vegetation Type

The lakeplain prairie vegetation type had 2 management units; SU1 and SU3. These units were small and yielded no edge making only the comparisons between exclosures and open areas possible. We first looked at horizontal cover and found no significant differences with the lakeplain prairie vegetation type, SU1 or SU3 between all exclosures and all open areas because the mean horizontal cover values were 80-100% for all measurements ($P>0.1$, $\alpha=0.10$) (Table 3.11).

Comparing the mean vertical cover values for the lakeplain prairie vegetation type, SU1, and SU3 found no significant differences between all exclosures and open areas. All mean values were 100% for vertical cover ($P>0.1$, $\alpha=0.10$) (Table 3.12).

Within the lakeplain prairie vegetation type we found no significant differences between the exclosures (3.8) and open areas (4.8) for the mean species richness values ($P>0.1$, $\alpha=0.10$) (Table 3.13). We found no significant differences of the mean species richness values within SU1 and SU 3 when comparing mean exclosure values of 3.6 and 4.1 respectively to mean open area values of 4.8 and 4.5 respectively ($P>0.1$, $\alpha=0.10$) (Table 3.13).

When comparing the total above ground biomass of the lakeplain prairie vegetation type we found no significant differences when comparing the means of exclosures (206.4kg/ha) to open areas (179.6kg/ha) ($P>0.1$, $\alpha=0.10$) (Table 3.14). Within SU1 and SU3 we found no significant differences when comparing the exclosure means of 193.9kg/ha and 221.0kg/ha respectively to the open area means of 173.1kg/ha and 189.7kg/ha respectively ($P>0.1$, $\alpha=0.10$)

(Table 3.14). We also found no significant difference between the mean seed biomass of the exclosures (29.4kg/ha) and open areas (23.8) within the lakeplain prairie vegetation type ($P>0.1$, $\alpha=0.10$) (Table 3.15). When comparing the mean seed biomass of SU1 and SU3 we found no significant difference when comparing the exclosure means of 25.7kg/ha and 31.7kg/ha to the open area means of 26.5kg/ha and 18.1kg/ha respectively ($P>0.1$, $\alpha=0.10$) (Table 3.15).

Bottomland Hardwood Forest Vegetation Type

Within the bottomland hardwood forest vegetation type we found no significant differences between all exclosure and open areas or within any individual stand for mean horizontal cover within the $<0.5\text{m}$ height strata, $0.5\text{-}1.0\text{m}$ height strata, and $>1.0\text{m}$ height strata because all values were 0-20% ($P>0.1$, $\alpha=0.10$) (Table 3.16). When looking at mean vertical cover we found no significant differences for the bottomland hardwood forest vegetation type between exclosures (37.9%) values and open areas (36.8%) within the $>1.0\text{m}$ height strata ($P>0.1$, $\alpha=0.10$) (Table 3.17). We found no significant differences for mean vertical cover within any of the individual stands for the $>1.0\text{m}$ height strata between exclosures and open areas and report exclosure means 80.6%, 14.0%, 16.1%, 29.6%, 46.6%, and 39.35 within stands 1-6 respectively and open area means of 77.0%, 17.5%, 15.7%, 31.6%, 46.0%, and 37.6% within stands 1-6 respectively ($P>0.1$, $\alpha=0.10$) (Table 3.17). Within the $1.0\text{-}2.0\text{m}$ height strata we found no significant differences in mean vertical cover between the exclosures and open areas with the bottomland hardwood forest vegetation type or within any of the individual stands because all values were 0.0% ($P>0.1$, $\alpha=0.10$) (Table 3.17). Within the $<2.0\text{m}$ height strata we found no significant differences of the mean vertical cover between exclosures (85.7%) and open areas (84.2%) for bottomland hardwood forest vegetation type ($P>0.1$, $\alpha=0.10$) (Table 3.17). We found no significant differences for mean vertical cover within any of the individual stands for

the <2.0m height strata between exclosures and open areas and report exclosure means of 83.3%, 83.3%, 83.3%, 88.3%, 86.6%, and 88.3% for stands 1-6 respectively and open area means of 90.0%, 85.0%, 80.0%, 81.6%, 91.6%, and 88.3% within stands 1-6 respectively ($P>0.1$, $\alpha=0.10$) (Table 3.17).

Within the bottomland hardwood forest vegetation type we found no significant differences for species richness between exclosures (3.7) and open areas (3.1) ($P>0.1$, $\alpha=0.10$) (Table 3.18). We also found no significant differences between any of the individual stands exclosures and open areas and found exclosure means for species richness to be 3.0, 3.0, 4.0, 3.0, 4.0, and 4.0 for exclosures in stands 1-6 respectively and means within the open areas to be 3.0, 2.0, 3.0, 4.0, 2.0, and 4.0 within stands 1-6 respectively ($P>0.1$, $\alpha=0.10$) (Table 3.18).

In the future we would also recommend sampling stem densities of woody species at <1m, 1-3m and >3m height strata. We would also recommend recording average diameter at breast height in trees >3m, because deer prefer to feed on the leaves and shoots of new growth of woody plant species and measuring this variable within exclosures and open areas might show if browsing pressure is too high (Johnson et al. 1995).

DISCUSSION

White-tailed deer at high densities can be a keystone herbivore and negatively impact forest community composition, structure, and biomass, however, little is known on the effects deer herbivory can have on the wetland vegetation type they use to fulfill life requisites (Kraft et al. 2004, Rooney and Waller 2003, Rooney 2001). Stewart et al. (2006) found that deer feed heavily in the edge of croplands that were surrounded by forests. This may be why in MSU 6 we found the exclosures in the edge region had significantly more seed biomass than the edge open

areas. Williamson and Hirth (1985) and Braun (1996) also found deer foraging to negatively impact the edges of crop fields more than the core areas of those fields. The reason we may have not seen significant difference between above ground biomass but only in the seed biomass in MSU 6 between the edge exclosures and opens areas is that deer sometimes feed on the flowers of plants (Urbanek 2012, Rooney 2001). If the flower of a plant is eaten late enough in the growing season the plants may not be able to produce another flower and therefore seed productivity (Kettering et al. 2009). We may have been seeing this describe occurrence in MSU 6 which is why seed biomass was significantly different within edge exclosures and open areas but total above ground biomass was not.

Our results quantifying minimal to no effects of deer herbivory on wetland plant vegetation types may be attributed to the lack of preferred spring and summer foods within these vegetation types. Hiller (2007), Miranda and Porter (2003), and Pusateri (2003) all found white-tailed deer selecting for agriculture vegetation types when foraging for spring and summer foods. Hiller (2007) and Pusateri (2003) did document deer using wetland vegetation types during the spring and summer months for feeding and hiding cover but they were not the most important vegetation types but Johnson et al. (1995) found white-tailed deer do prefer to feed on new growth of woody plant species. Dostaler et al. (2010) and Daigel et al. (2004) found that when agriculture was present in a landscape and available to white-tailed deer for feeding, agricultural crops made up a larger portion of the diet than woody plant species, forbs and grasses than in areas where agricultural crops were limited. These results suggest agricultural crops may be acting as preferred foods, over wetland plant species, for white-tailed deer within this region of Michigan because of their abundance immediately adjacent to the SNWR.

Russel et al. (2001) commented that the effects of deer herbivory within forest vegetation types are not immediate effects but compounding and being to show after years of heavy browsing. In future years we may anticipate different results than from our initial 2 years within the bottomland hardwood forest vegetation type due to the exclusion of deer from plants within the exclosures, since negative impacts to regeneration and recruitment of forest vegetation sites is often seen after a longer time period (Raymer 2000, Russell et al. 2001).

Additionally, we also may not have seen any negative effects to plant species richness, horizontal and vertical cover, total above ground biomass, or seed biomass because deer densities at SNWR have been are highly managed over the last 15 years. Biologists at SNWR try to maintain estimated deer density of ~1.5deer/ha within the refuge boundary. To meet this goal, they issue specific hunting permit regulations every fall. The estimated number of deer has been greatly reduced through hunting efforts from ~4.2 deer/ha in the early 1990's to ~1.5 deer/ha today (Fig. 3.1). If we had conducted this study in the early 1990's we may have seen drastically different results. Urbanek et al.'s (2012) exclosure study documented high deer densities (3.0 deer/ha) within savanna vegetation types negatively impacted savanna plant communities by reducing the number of flowering individuals and species diversity. Anderson et al. (2004) also found the community composition within a tallgrass prairie to decrease in times of intense deer herbivory (6.0 deer/ha). Although this study did not show how deer herbivory could be a challenge to manage within wetland vegetation types previous research has showed that deer densities at high levels are what cause changes to the plant communities.

MANAGEMENT IMPLICATIONS

High densities of white-tailed deer can pose challenges to natural resource managers in landscapes dominated by wetlands where deer densities are not highly managed. Those managers may want to avoid planting costly and highly preferred plant species for waterfowl within the edge of fields or management units. Natural resource managers may expect to find fewer flowering and fruiting individuals in wetland landscapes where deer densities are high but when deer densities are lower we may not see negative impacts of deer herbivory to a diversity of wetland plant communities.

Overall low densities of deer (~1.5 deer/ha) on our study area did not negatively impact wetland plant communities. In certain instances we may see more effects of herbivory around the edge of management units or fields when they are surrounded by preferred vegetation types like deciduous forest vegetation types. Managing for lower deer densities in landscapes dominated by wetlands may help reduce potential negative impacts to wetland plant communities and help avoid seeing plant community changes therefore allowing biologists to achieve other goals and objectives such as maintaining habitat for migratory and resident waterfowl.

Table 3.1. Average horizontal cover <1.0m (standard errors) for moist soil (MSU) vegetation types at Shiawassee National Wildlife Refuge 2011 and 2012. A two tailed t-test was used to compare average horizontal cover between all exclosures, all open areas, core exclosures vs. core open areas, and edge exclosures vs. edge open areas ($\alpha=0.10$).

Unit	Mean Horizontal Cover (%)					
	All Exclosures	All Open Areas	Core Exclosures	Core Open Areas	Edge Exclosures	Edge Open Areas
All MSU	80-100 (0.3)	80-100 (0.3)	80-100 (0.0)	80-100 (0.4)	80-100 (0.4)	80-100 (0.0)
MSU 1	80-100 (0.3)	80-100 (0.0)	80-100 (0.4)	80-1000 (0.0)	80-100 (0.0)	80-100 (0.0)
MSU 2E	80-100 (0.0)	80-100 (0.0)	80-100 (0.0)	80-100 (0.0)	80-100 (0.0)	80-100 (0.0)
MSU 2W	80-100 (0.0)	80-100 (0.0)	80-100 (0.0)	80-100 (0.0)	80-100 (0.0)	80-100 (0.0)
MSU 6	80-100 (0.0)	80-100 (0.0)	80-100 (0.0)	80-100 (0.0)	80-100 (0.0)	80-100 (0.0)

Table 3.2. Mean percent vertical cover <1.0m (standard errors) for the moist soil (MSU) vegetation type and each management unit individually within the moist soil vegetation type at Shiawassee National Wildlife Refuge, 2011 and 2012. A two tailed t-test was used to compare means between all exclosures, all open areas, core exclosures vs. core open areas, and edge exclosures vs. edge open areas ($\alpha=0.10$).

Unit	Mean Vertical Cover (%)					
	All Exclosures	All Open Areas	Core Exclosures	Core Open Areas	Edge Exclosures	Edge Open Areas
All MSU	96.6 (0.4)	96.9 (0.5)	97.2 (0.4)	97.2 (0.4)	96.6 (0.5)	96.1 (0.6)
MSU 1	95.8 (0.5)	95.8 (0.5)	93.3 (0.5)	93.3 (0.6)	98.3 (0.3)	98.3 (0.3)
MSU 2E	95.0 (0.3)	94.2(0.7)	98.3 (0.3)	98.3 (0.3)	91.7 (0.5)	90.0 (0.3)
MSU 2W	100 (0.0)	100 (0.0)	100 (0.0)	100 (0.0)	100 (0.0)	100 (0.0)
MSU 6	98.7 (0.2)	98.3 (0.2)	100 (0.0)	100 (0.0)	97.4 (0.3)	96.6 (0.4)

Table 3.3. Mean species richness (standard errors) for the moist soil (MSU) vegetation type and each management unit individually within the moist soil vegetation type at Shiawassee National Wildlife Refuge, 2011 and 2012. A two tailed t-test was used to compare means between all exclosures, all open areas, core exclosures vs. core open areas, and edge exclosures vs. edge open areas ($\alpha=0.10$).

Unit	Mean Species Richness					
	All Exclosures	All Open Areas	Core Exclosures	Core Open Areas	Edge Exclosures	Edge Open Areas
All MSU	5.7 (0.1)	5.3 (0.1)	5.9 (0.2)	5.9 (0.1)	5.0 (0.2)	5.3 (0.3)
MSU 1	6.6 (0.8)	6.0 (0.5)	6.0 (0.6)	6.3(0.5)	6.0 (1.5)	7.0 (1.0)
MSU 2E	5.5 (0.6)	5.1 (0.5)	5.3 (0.8)	5.3 (0.8)	5.6 (0.9)	5.0 (0.7)
MSU 2W	5.3 (0.7)	5.3 (0.5)	7.2 (0.7)	6.2 (0.8)	3.5 (0.6)	4.3 (0.5)
MSU 6	5.5 (0.4)	5.1 (0.4)	5.3 (0.6)	6.0 (0.6)	5.0 (0.4)	4.8 (0.6)

Table 3.4. Mean above ground biomass production (standard errors) for the moist soil (MSU) vegetation type and each management unit individually within the moist soil vegetation type at Shiawassee National Wildlife Refuge, 2011 and 2012. A two tailed t-test was used to compare means between all exclosures, all open areas, core exclosures vs. core open areas, and edge exclosures vs. edge open areas ($\alpha=0.10$).

Unit	Mean Above Ground Biomass (kg/ha)					
	All Exclosures	All Open Areas	Core Exclosures	Core Open Areas	Edge Exclosures	Edge Open Areas
All MSU	160.0 (3.0)	178.7 (3.8)	157.1 (4.0)	183.3 (5.3)	163.3 (4.5)	174.1 (5.5)
MSU 1	99.1 (51.1)	141.8 (83.7)	138.4 (67.8)	102.0 (121.1)	145.0 (77.7)	96.4 (119.3)
MSU 2E	143.3 (54.4)	152.2 (56.8)	140.7 (72.9)	164.2 (79.0)	146.2 (83.7)	38.5 (83.1)
MSU 2W	159.8 (56.8)	169.0 (74.9)	148.4 (63.9)	164.0 (95.4)	173.1 (96.6)	173.1 (115.0)
MSU 6	201.0 (62.2)	227.6 (79.5)	199.7 (92.1)	236.1 (188.5)	202.6 (84.0)	218.1 (106.8)

Table 3.5 Mean seed biomass production (standard errors) for the moist soil (MSU) vegetation type and each management unit individually within the moist soil vegetation type at Shiawassee National Wildlife Refuge, 2011 and 2012. A two tailed t-test was used to compare means between all exclosures, all open areas, core exclosures vs. core open areas, and edge exclosures vs. edge open areas ($\alpha=0.10$).

Unit	Mean Seed Biomass (kg/ha)					
	All Exclosures	All Open Areas	Core Exclosures	Core Open Areas	Edge Exclosures	Edge Open Areas
All MSU	39.4 (7.0)	35.9 (5.9)	33.8 (5.2)	39.5 (6.2)	49.2 (9.5)	31.8 (5.7)
MSU 1	12.7 (6.5)	24.2 (12.9)	8.6 (7.2)	14.8 (7.6)	33.5 (10.0)	15.0 (24.8)
MSU 2E	6.8 (3.8)	11.2 (7.9)	5.3 (3.3)	11.4 (9.5)	9.7 (8.5)	11.3 (13.8)
MSU 2W	33.3 (22.0)	31.5 (18.2)	21.5 (11.2)	35.1 (26.9)	49.9 (46.5)	28.6 (25.3)
MSU 6	75.6 (20.6)	58.0 (18.4)	63.3 (26.7)	65.55 (27.5)	133.4 (33.3)*	49.8 (24.2)*

*Averages followed by * are significantly different from one another.

Table 3.6. Mean horizontal cover <1.0m (standard errors) for the perennial marsh (PM) vegetation type and each management unit individually at Shiawassee National Wildlife Refuge, 2011 and 2012. A two tailed t-test was used to compare means between all exclosures, all open areas, core exclosures vs. core open areas, and edge exclosures vs. edge open areas ($\alpha=0.10$).

Unit	Mean Horizontal Cover (%)					
	All Exclosures	All Open Areas	Core Exclosures	Core Open Areas	Edge Exclosures	Edge Open Areas
All PM	60-80 (0.8)	60-80 (0.8)	20-40 (0.9)	20-40 (1.2)	80-100 (0.6)	80-100 (0.6)
Butch's Marsh	60-80 (0.8)	60-80 (0.8)	0-20 (1.3)	20-40 (1.3)	80-100 (0.0)	80-100 (0.0)
Pool 1A	60-80 (0.8)	60-80 (0.8)	20-40 (0.6)	20-40 (1.0)	80-100 (1.3)	80-100 (1.3)

Table 3.7. Mean percent vertical cover <1.0m (standard errors) for the perennial marsh (PM) vegetation type and each management unit individually at Shiawassee National Wildlife Refuge, 2011 and 2012. A two tailed t-test was used to compare means between all exclosures, all open areas, core exclosures vs. core open areas, and edge exclosures vs. edge open areas ($\alpha=0.10$).

Unit	Mean Vertical Cover (%)					
	All Exclosures	All Open Areas	Core Exclosures	Core Open Areas	Edge Exclosures	Edge Open Areas
All PM	54.5 (17.7)	55.8 (17.7)	30.8 (20.8)	34.1 (23.3)	78.3 (17.7)	77.4 (17.5)
Butch's Marsh	64.1 (17.3)	64.1 (17.3)	36.6 (27.2)	36.6 (27.2)	91.6 (3.3)	91.6 (3.3)
Pool 1A	45.0 (18.2)	47.6 (18.1)	25.0 (14.4)	31.8 (19.5)	65.0 (32.5)	63.3 (31.8)

Table 3.8. Mean species richness (standard errors) for the perennial marsh (PM) vegetation type and each management unit individually at Shiawassee National Wildlife Refuge, 2011 and 2012. A two tailed t-test was used to compare means between all exclosures, all open areas, core exclosures vs. core open areas, and edge exclosures vs. edge open areas ($\alpha=0.10$).

Unit	Mean Species Richness					
	All Exclosures	All Open Areas	Core Exclosures	Core Open Areas	Edge Exclosures	Edge Open Areas
All PM	3.6 (0.4)	3.6 (0.5)	4.0 (0.6)	4.0 (0.7)	3.3 (0.6)	3.3 (0.9)
Butch's Marsh	2.0 (0.3)	1.6 (0.2)	2.5 (0.5)	1.5 (0.5)	1.6 (0.3)	1.6 (0.3)
Pool 1A	4.5 (0.4)	4.7 (0.5)	4.6 (0.6)	5 (0.4)	4.4 (0.6)	4.4 (1.1)

Table 3.9. Mean total above ground biomass (standard errors) for the perennial marsh (PM) vegetation type and each management unit individually at Shiawassee National Wildlife Refuge, 2011 and 2012. A two tailed t-test was used to compare means between all exclosures, all open areas, core exclosures vs. core open areas, and edge exclosures vs. edge open areas ($\alpha=0.10$).

Unit	Mean Total Above Ground Biomass (kg/ha)					
	All Exclosures	All Open Areas	Core Exclosures	Core Open Areas	Edge Exclosures	Edge Open Areas
All PM	296.0 (39.3)	313.2 (38.1)	249.7 (38.6)	238.9 (37.8)	346.0 (40.2)	399.3 (37.5)
Butch's Marsh	535.1 (283.1)	663.6 (251.4)	387.0 (424.8)	571.5 (586.6)	683.6 (402.2)	737.3 (183.0)
Pool 1A	247.1(90.7)	243.1 (89.5)	219.8 (149.9)	185.7 (109.0)	265.3 (118.1)	314.8 (154.1)

Table 3.10. Mean total seed mass (standard errors) for the perennial marsh vegetation type and each management unit individually at Shiawassee National Wildlife Refuge, 2011 and 2012. Pool 1A was the only perennial marsh management unit where seeds were present. A two tailed t-test was used to compare means between all exclosures, all open areas, core exclosures vs. core open areas, and edge exclosures vs. edge open areas ($\alpha=0.10$).

Unit	Mean Seed Biomass (kg/ha)					
	All Exclosures	All Open Areas	Core Exclosures	Core Open Areas	Edge Exclosures	Edge Open Areas
Pool 1A	25.0 (13.6)	29.3 (9.0)	12.7 (6.1)	25.2 (15.1)	36.3 (26.8)	32.7 (12.4)

Table 3.11. Mean horizontal cover <1.0m (standard errors) for the lakeplain prairie (LPP) vegetation type and each management unit individually at Shiawassee National Wildlife Refuge, 2011 and 2012. A two tailed t-test was used to compare means between all exclosures and all open areas ($\alpha=0.10$).

Unit	Mean Horizontal Cover (%)	
	Exclosure	Open Areas
All LPP	80-100 (0.0)	80-100 (0.0)
SU1	80-100 (0.0)	80-100 (0.0)
SU3	80-100 (0.0)	80-100 (0.0)

Table 3.12. Mean vertical cover <1.0m (standard errors) for the lakeplain prairie (LPP) vegetation type and each management unit individually at Shiawassee National Wildlife Refuge, 2011 and 2012. A two tailed t-test was used to compare means between all exclosures and all open areas ($\alpha=0.10$).

Unit	Mean Vertical Cover (%)	
	Exclosure	Open Areas
All LPP	100 (0.0)	100 (0.0)
SU1	100 (0.0)	100 (0.0)
SU3	100 (0.0)	100 (0.0)

Table 3.13. Mean species richness (standard errors) for the lakeplain prairie (LPP) vegetation type and each management unit individually at Shiawassee National Wildlife Refuge, 2011 and 2012. A two tailed t-test was used to compare means between all exclosures and all open areas ($\alpha=0.10$).

Unit	Mean Species Richness	
	Exclosure	Open Areas
All LPP	3.8 (0.4)	4.6 (0.5)
SU1	3.6 (0.3)	4.8 (0.5)
SU3	4.1 (0.5)	4.5 (0.6)

Table 3.14. Mean above ground biomass (standard errors) for the lakeplain prairie (LPP) vegetation type and each management unit individually, at Shiawassee National Wildlife Refuge, 2011 and 2012. A two tailed t-test was used to compare means between all exclosures and all open areas ($\alpha=0.10$).

Unit	Mean Above Ground Biomass (kg/ha)	
	Exclosure	Open Areas
All LPP	206.4 (2.9)	179.6 (2.0)
SU1	193.9 (67.3)	173.1 (56.0)
SU3	221.0 (100.7)	189.7 (71.1)

Table 3.15. Mean seed biomass (standard errors) for the lakeplain prairie (LPP) vegetation type and each management unit individually, at Shiawassee National Wildlife Refuge, 2011 and 2012.

A two tailed t-test was used to compare means between all exclosures, all open areas ($\alpha=0.10$).

Unit	Mean Seed Biomass (kg/ha)	
	Exclosure	Open Areas
All LPP	29.4 (3.1)	23.8 (2.5)
SU1	25.7 (9.9)	26.5 (10.1)
SU3	31.7 (16.6)	18.1 (6.9)

Table 3.16. Mean horizontal cover (standard errors) for the bottomland hardwood forest vegetation type and each stand individually, at Shiawasse National Wildlife Refuge, 2011 and 2012. 3 height strata were used to make measurements <0.5m, 0.5-1.0m, and >1.0m. A two tailed t-test was used to compare means between all exclosures and all open areas ($\alpha=0.10$).

Unit	Mean Horizontal Cover (%)					
	<0.5m		0.5-1.0m		>1.0m	
	Exclosures	Open Areas	Exclosures	Open Areas	Exclosures	Open Areas
All Stands	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)
1	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)
2	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)
3	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)
4	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)
5	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)
6	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)	0-20 (0.0)

Table 3.17. Mean vertical cover (standard errors) for the bottomland hardwood forest vegetation type and each stand individually at Shiawassee National Wildlife Refuge, 2011 and 2012. 3 height strata were used to make measurements <1.0m, 1.0-2.0m, and >2.0m. A two tailed t-test was used to compare means between all exclosures and all open areas ($\alpha=0.10$).

Stand #	Mean Vertical Cover (%)					
	<1.0m		1.0-2.0m		>2.0m	
	Exclosures	Open Areas	Exclosures	Open Areas	Exclosures	Open Areas
All Stands	37.9 (0.9)	36.8 (0.6)	0.0 (0.0)	0.0 (0.0)	85.7 (0.8)	84.2 (1.6)
1	80.6 (0.3)	77.0 (0.4)	0.0 (0.0)	0.0 (0.0)	83.3 (0.4)	90.0 (0.3)
2	14.0 (0.2)	17.5 (0.5)	0.0 (0.0)	0.0 (0.0)	83.3 (0.3)	85.0 (0.2)
3	16.1 (0.2)	15.7 (0.4)	0.0 (0.0)	0.0 (0.0)	83.3 (0.3)	80.0 (0.3)
4	29.6 (0.2)	31.6 (0.4)	0.0 (0.0)	0.0 (0.0)	88.3 (0.3)	81.6 (0.2)
5	46.6 (0.4)	46.0 (0.5)	0.0 (0.0)	0.0 (0.0)	86.6 (0.6)	91.6 (0.4)
6	39.3 (0.2)	37.6 (0.3)	0.0 (0.0)	0.0 (0.0)	88.3 (0.3)	88.3 (0.5)

Table 3.18. Mean overstory species richness (standard errors) for the bottomland hardwood forest vegetation type and each stand individually, at Shiawassee National Wildlife Refuge, 2011 and 2012. A two-tailed t-test for used to compare means between exclosures and open areas ($\alpha=0.10$).

Stand #	Mean Overstory Species Richness	
	Exclosure	Open Area
All Stands	3.5 (0.1)	3.1 (0.2)
1	3 (0.0)	3 (0.0)
2	3 (0.0)	2 (0.0)
3	4 (0.0)	3 (0.0)
4	3 (0.0)	4 (0.0)
5	4 (0.0)	3 (0.0)
6	4 (0.0)	4 (0.0)

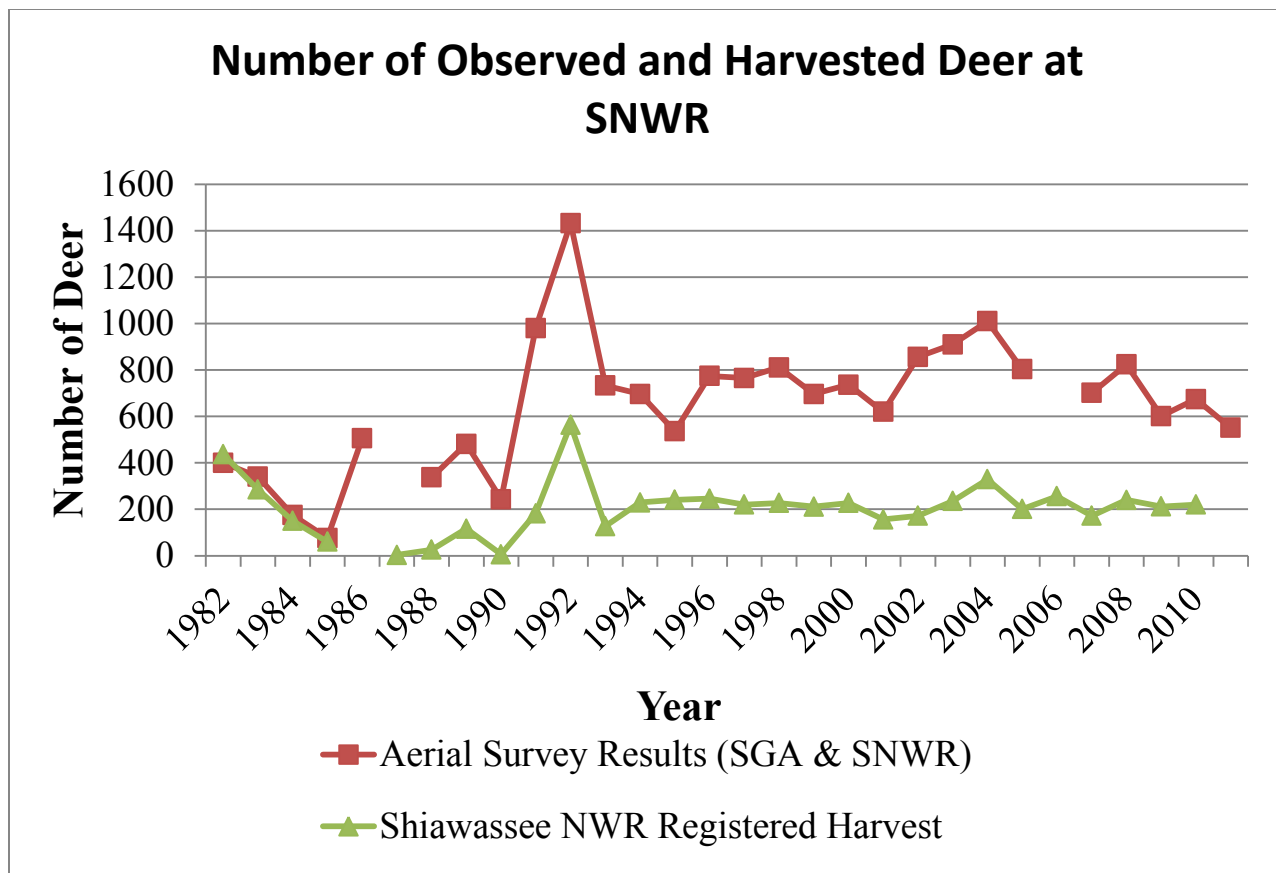


Figure 3.1 Deer estimates and hunter harvest numbers of Shiawassee National Wildlife Refuge

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APPENDICES

APPENDIX A

Locations of forest exclosures and sample data sheet for continuation of herbivory monitoring
within bottomland hardwood forest vegetation type

Table A.1. Location of exclosures and paired open areas within forested stands at Shiawassee National Wildlife Refuge. Open area locations are referenced in cardinal direction and distance from exclosure.

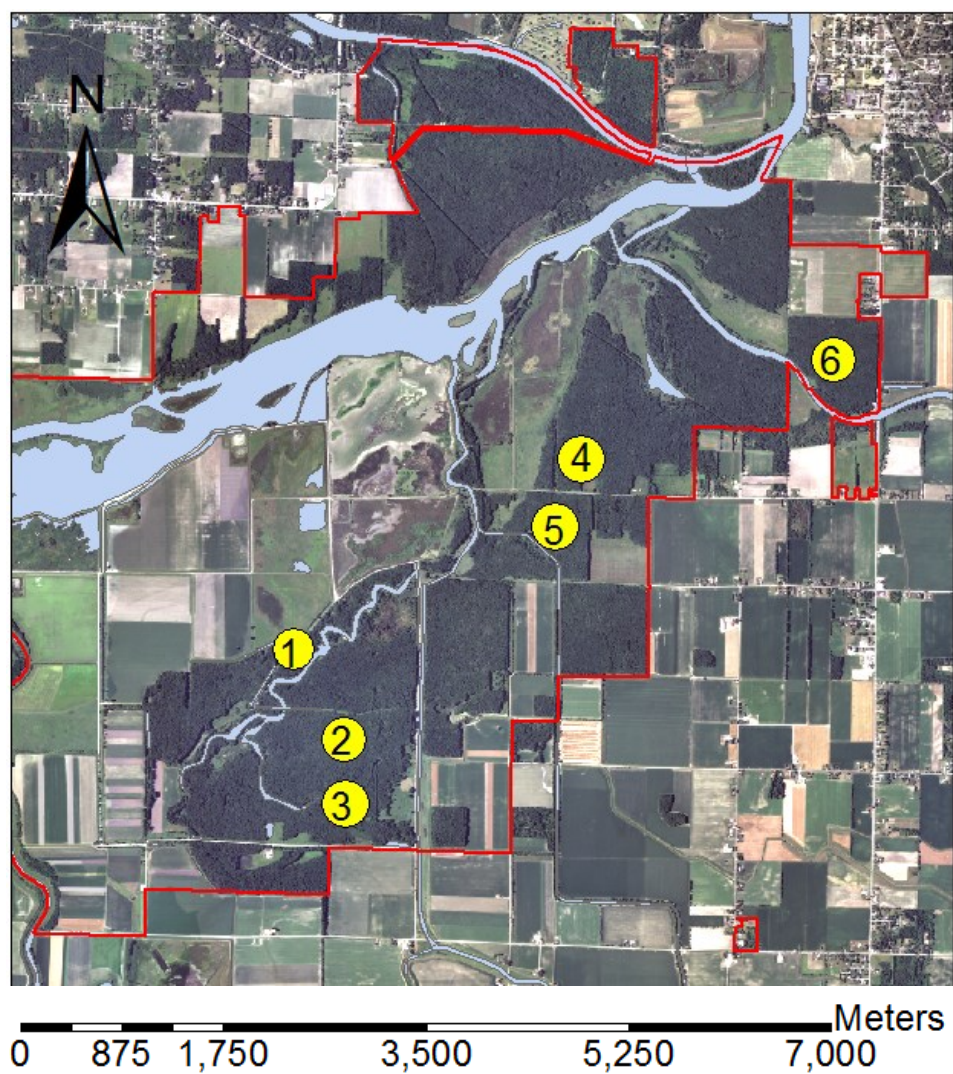
Exclosure Number	Location (Degrees Minutes Seconds)	Location (from exclosure)
	Exclosure	Open Area
1	N 43 ⁰ 21' 2.6" W 84 ⁰ 00' 30.9"	10m from west side
2	N 43 ⁰ 20' 12.3" W 84 ⁰ 00' 30.3"	10m from south side
3	N 43 ⁰ 20' 20.6" W 84 ⁰ 01' 0.3"	10m from south side
4	N 43 ⁰ 21' 33.9" W 83 ⁰ 59' 16.7"	10m from north side
5	N 43 ⁰ 21' 23.9" W 83 ⁰ 59' 29.3"	10m from south side
6	N 43 ⁰ 22' 3.9" W 83 ⁰ 57' 28.2"	10m from west side

Table A.2. Example data sheet for continued collection of horizontal cover, vertical cover, and overstory species richness at each exclosure and open area within the forest exclosure sites. We recommend following the methods described in Chapter 3.

Exclosure #	Location		
Variable	Measurement #	Exclosure	Open Area
Horizontal Cover (<0.5m)	1		
	2		
	3		
Horizontal Cover (0.5-1m)	1		
	2		
	3		
Horizontal Cover (>1.0m)	1		
	2		
	3		
Vertical Cover (<1.0m)	1		
	2		
	3		
Vertical Cover (1-2m)	1		
	2		
	3		
Vertical Cover (>2.0m)	1		
	2		
	3		
Species Richness	1		
List of Overstory Species Present			

Table A.3. List of species observed within exclosures and open areas at bottomland hardwood forest sites. An X indicates when a species was present.

Species		Site Number					
Common Name	Scientific Name	1	2	3	4	5	6
American Beech	<i>Fagus grandifolia</i>			X			
American Elm	<i>Ulmus americana</i>	X	X	X			
Basswood	<i>Tilia Americana</i>				X		
Cottonwood	<i>Populus deltoides</i>		X	X	X	X	X
Shagbark Hickory	<i>Carya ovate</i>	X		X			
Silver Maple	<i>Acer saccharinum</i>	X	X	X	X	X	X
Sugar Maple	<i>Acer saccharum</i>		X	X			
White Oak	<i>Quercus alba</i>			X		X	



Legend

- SNWR Boundary
- Exclosure number and approximate location

Figure A.1. Aerial image of Shiawassee National Wildlife Refuge, refuge boundary outlined in red. Each numbered circle indicates approximately where an exclosure and paired open area are located within the forested stand.

APPENDIX B

Research and outreach activities

RESEARCH ACTIVITIES

PROFESSIONAL PRESENTATIONS (name in bold indicates presenter)

Graduate Student Organization Research Symposium (Department of Fisheries and Wildlife, MSU) - January 2013 – East Lansing MI

- Evaluating deer impacts to wetland vegetation types

S. Longstaff, H. Campa, III, A. Locher, S.R. Winterstein, E. Dunton, and S. Kahl

Stewardship Network Conference – January 2013 – East Lansing, MI

- Hunting not just recreation but also conservation: evaluating how deer hunting opportunities help conserve wetland vegetation types and waterfowl food resources at Shiawassee National Wildlife Refuge

S. Longstaff, H. Campa, III, A. Locher, S.R. Winterstein, E. Dunton, and S. Kahl

Midwest Fish and Wildlife Conferences – December 2012 – Wichita, Kansas

- Evaluating wetland use by white-tailed deer and the habitat suitability wetland vegetation types provide for them

S. Longstaff, H. Campa, III, A. Locher, S.R. Winterstein, E. Dunton, and S. Kahl

Midwest Fish and Wildlife Conference – December 2011 – Des Moines, Iowa

- Behind the Fence: Evaluating how white-tailed deer impact wetland vegetation types

S. Longstaff, H. Campa, III, S.R. Winterstein, E. Dunton and S. Kahl

OUTREACH ACTIVITIES

PRESENTATIONS (name in bold indicates presenter)

Ducks Unlimited – March 2013 – Ann Arbor, MI

-Bucks and Ducks: Evaluating how wetlands are impacted by white-tailed deer

S. Longstaff, H. Campa, III, S.R. Winterstein, E. Dunton, S. Kahl, and A. Locher

Shiawassee National Wildlife Refuge – January 2013- Saginaw, MI

-Yearly research update

S. Longstaff, H. Campa, III, S.R. Winterstein, E. Dunton, S. Kahl, and A. Locher

Friends of Shiawassee National Wildlife Refuge Seminar Series – June 2012 – Saginaw, MI

- Within the Levees: Taking a look at some of the research going on at Shiawassee National Wildlife Refuge

S. Longstaff, H. Campa, III, S.R. Winterstein, E. Dunton, S. Kahl, and A. Locher

-A presentation given to the general public highlighting current research project being conducted at Shiawassee National Wildlife Refuge. One of the goals of the presentation was to help bridge the gap between the scientific community and the non-science community. The presentation helped show why research was being conducted and what the results would potentially be used for.

Shiawassee National Wildlife Refuge – January 2012- Saginaw, MI
-Yearly research update
S. Longstaff, H. Campa, III, S.R. Winterstein, E. Dunton, S. Kahl

SUBMITTED ARTICLES

S. Longstaff. 2014. A Buck in the Muck?: Evaluating how wetlands provide habitat for white-tailed deer and how deer use affects birds within those wetlands. Spotlight.
- Article will be published in the upcoming 2014 issue of Spotlight Magazine.

PROFESSIONAL MEMBERSHIPS

Member of The Wildlife Society (2011- present)

Member of the North Central Section
Member of the Michigan Chapter

Member of the Graduate Student Organization (GSO) (2010-present)

- An organization for the graduate students in the Department of Fisheries and Wildlife at Michigan State University. The organization offers opportunities for students to develop themselves professionally, get involved in graduate student life, and maintain their health and wellness while attending Michigan State University. The organization also provides students with travel funding and fundraising opportunities along with weekly seminars and other educational opportunities to help gain exposure to the entire field of Fisheries and Wildlife.

Spotlight Committee Member (2010 – present)

- Spotlight is a non-profit magazine run by volunteer graduate students in the Department of Fisheries and Wildlife at Michigan State University. The magazine is written, designed, edited, published, and distributed by Fisheries and Wildlife graduate students. It highlights the research and community outreach projects the department is currently working on.

- Layout Designer: 2010 – present
- Editor: 2011 – present
- Distribution Manager: 2011 – present