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SMALL MAMMAL POPULATIONS IN SWITCHGRASS STANDS MANAGED FOR BIOMASS PRODUCTION COMPARED TO HAY AND CORN FIELDS IN KENTUCKY

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ABSTRACT OF THESIS

SMALL MAMMAL POPULATIONS IN SWITCHGRASS STANDS MANAGED FOR BIOMASS PRODUCTION COMPARED TO HAY AND CORN FIELDS IN KENTUCKY

Switchgrass (*Panicum virgatum*), a native warm-season grass, has been investigated as a renewable energy crop that may provide viable wildlife habitat. This study investigated small mammal populations in switchgrass, hay, and corn to assess the relative habitat quality. Four, three-night trapping sessions were conducted at four locations in Kentucky using Sherman livetraps. Trapping occurred in spring (before first hay harvest), summer, fall (before switchgrass and corn harvest), and winter (post-harvest). Relative abundance of small mammals, calculated using a capture per unit effort index (per 100 trapnights), and mean taxonomic richness were used to compare habitats. Switchgrass had a significantly greater mean taxonomic richness than hay but not corn; however, four genera were captured in switchgrass and only two in corn. Switchgrass had a greater relative abundance of small mammals than hay during the summer, and corn and hay during the fall. Vegetative cover was positively correlated with relative abundance of small mammals. No-till corn and three year old switchgrass had a greater relative abundance of small mammals than conventionally tilled corn and two year old switchgrass, respectively. In conclusion, switchgrass stands managed as a renewable energy crop has the potential to be viable wildlife habitat for some small mammal species.

KEYWORDS: switchgrass (*Panicum virgatum*), small mammals, wildlife habitat, biomass, renewable energy crop

Laura Jane Mary Schwer

February 22, 2011

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By

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Lexington, Kentucky

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I would like to dedicate my work to my husband, Donald Schwer III, my loving parents, William and Mary Jane Peterman, and my brothers, Matthew and Devin Peterman, for their support, encouragement, and positive enthusiasm throughout my education.

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CHAPTER I: Introduction

Currently, the majority of the energy produced in the United States is derived from fossil fuels (United States 2010). In 2008, 84% of the total energy produced was from fossil fuels with the remaining 8% from nuclear power, and 7% from renewable energy sources (United States 2010). Due to increasing energy demand (Fletcher et al. 2010, Tilman et al. 2006, Fargione et al. 2008), food demand and security (Tilman et al. 2006), interest in national energy independence (Fargione et al. 2009, Tilman et al. 2006, McLaughlin & Walsh 1998, Paine et al. 1996), volatile petroleum prices (Fletcher et al. 2010), and the need to reduce carbon emissions (Fletcher et al. 2010, Fargione et al. 2009, Tilman et al. 2006, Fargione et al. 2008), there is a growing interest in producing more energy from renewable sources. There are multiple renewable energy options, but not all are suited for every geographical area.

One potential option for the state of Kentucky is producing electricity by co-firing biomass of renewable energy crops (REC) with coal in existing coal-burning facilities (Jensen et al. 2007). Producing RECs, such as short-rotation woody crops (i.e. poplars (*Populus* (L.)) and willows (*Salix* (L.))) and perennial warm-season grasses (i.e. *Miscanthus x giganteus* and switchgrass (*Panicum virgatum* (L.))), is a viable option because of the abundant abandoned and marginal crop lands. According to Debolt et al. (2009), 21% of Kentucky's land area is in abandoned agricultural lands and mine lands. Abandoned marginal lands, as well as highly erodible lands and drained wetlands in agriculture production, are recommended for RECs (Paine et al. 1996) to avoid issues with food security, ecosystem loss, and global climate change (Campbell et al. 2008). Viable agricultural lands should be avoided due to potential increases in food cost and shortages (Blanco-Canqui 2010, Campbell et al. 2008), and annual row crop production is economically more competitive on these lands than RECS (Tolbert & Wright 1998). Conversion of native ecosystems and forest lands results in biodiversity loss (Tilman et al. 2006) and net carbon debts, carbon storage is less than released carbon dioxide (Campbell et al. 2008, Fargione et al. 2008). Abandoned marginal lands are also susceptible to erosion, soil stability, and water quality issues under annual row crop production; thus, they are ideal candidates for an herbaceous, perennial REC, like switchgrass (Blanco-Canqui 2010, Tolbert & Wright 1998, Paine et al. 1996).

At present, REC markets are still in the development phase, and the economic viability compared to coal is debated. Relatively high costs associated with biomass production for energy include establishment costs compared to annual row crops (Fargione et al. 2009, Paine et al. 1996) and transportation due to the bulkiness of the material (Paine et al. 1996). However, once the stand is established the maintenance costs are relatively low due to the low nutrient requirements (Paine et al. 1996) and limited weed control. Total biomass cost estimates greatly vary depending on current markets and prices of needed products including but not limited to seed, fertilizer, herbicides, land rental, and fuel (Parrish & Fike 2005). Most total cost estimates are not competitive with the current costs of coal (Paine et al. 1996). Switchgrass provides ~70% of the energy on a weight basis produced by coal; one Mg of switchgrass produces 17 to 18 GJ and one Mg of coal produces 27 to 30 GJ (Parrish & Fike 2005). According to these rates, the price of coal would need to be ~55% more per Mg of material than switchgrass to be economically viable based on energy produced (Parrish & Fike 2005). However, market development, the help of government cost-share programs to reduce establishment costs, government subsidies and mandates, and the inclusion of carbon neutral or carbon sequestration benefits may change the future economic viability of switchgrass (Paine et al. 1996). Long-term, reliable contracts between producers and power plants will also be needed to ensure a reliable supply of material and for economic benefits for producers (Paine et al. 1996).

Switchgrass is a warm-season, perennial bunch-type grass native to the North American Tallgrass Prairie currently investigated as a REC due to its adaptation to a wide range of environmental conditions and soil types, as well as large, relatively stable yields (Fletcher et al. 2010, Wullschleger et al. 2010, McLaughlin & Walsh 1998). In addition to use as a REC, switchgrass can be managed for summer grazing and as a hay crop for cattle (McLaughlin & Walsh 1998). Switchgrass stands may also provide additional habitat for wildlife (Blanco-Canqui 2010, Fletcher et al. 2010, Fargione et al. 2009, Jensen et al. 2007, Tilman et al. 2006, McLaughlin & Walsh 1998, Paine et al. 1996).

The perennial growth habit and extensive root system of switchgrass allows it to tolerate a wide-range of conditions and provides positive environmental benefits. Switchgrass is tolerant of poorly-drained and well-drained soils, nutrient-depleted lands, and low pH (Blanco-Canqui 2010), as well as drought, flooding (Blanco-Canqui 2010, Jensen et al. 2007), and windy conditions (Blanco-Canqui 2010). Some environmental benefits include reduced water and wind erosion (Blanco-Canqui 2010, Jensen et al. 2007, McLaughlin & Walsh 1998, Paine et al. 1996), low nutrient needs due to high nutrient-use efficiency (Fletcher et al. 2010, McLaughlin & Walsh 1998), and low pesticide requirements (Fletcher et al. 2010, McLaughlin & Walsh 1998). Additionally, decreased water runoff reduces the loss of agricultural chemicals (Jensen et al. 2007, Paine et al. 1996), nutrients, and sediment (Blanco-Canqui 2010) into nearby waters, enhanced nutrient cycling and storage (Blanco-Canqui 2010), and recharged groundwater supply (Blanco-Canqui 2010). Soils under switchgrass production can also improve over time (Tilman et al. 2006) with increased soil organic matter (Blanco-Canqui 2010, Jensen et al. 2007, McLaughlin & Walsh 1998), stability (Fletcher et al. 2010), aggregation (Blanco-Canqui 2010), porosity (Blanco-Canqui 2010, Jensen et al. 2007), water infiltration and holding capacity (Blanco-Canqui 2010, Jensen et al. 2007, McLaughlin & Walsh 1998), and sequestration of soil organic carbon (Blanco-Canqui 2010, Paine et al. 1996). McLaughlin and Walsh (1998) reported that soils under switchgrass production had soil organic carbon sequestration rates reaching 20 to 30 times greater than soils under annual row crops. Even though switchgrass yields are expected to be less on marginal lands compared to viable agricultural land (Paine et al. 1996), the environmental benefits are greater than the loss in yield.

There are two main ecotypes of switchgrass, upland and lowland, with many varieties within each type (Parrish & Fike 2005). Choosing the correct switchgrass ecotype and variety is important for maximizing production and increasing stand longevity (Parrish & Fike 2005). Local varieties are the most appropriate, because they are within the latitudes from which they originate (Fike et al. 2006). Upland varieties, such as Cave-In-Rock, have finer stems and higher percent leaf production, which results in better forage compared to lowland varieties (Parrish & Fike 2005). They originate from the colder areas of North America and perform better in semi-arid climates and drier soils (Parrish & Fike 2005). Lowland varieties, such as Kanlow and Alamo, are taller, coarser stemmed plants with greater yield potential and higher disease-resistance than upland varieties in the southern United States (Parrish & Fike 2005). They are native to areas that have higher rainfall and mild winter temperatures (Parrish & Fike 2005). Lowland varieties grow better in finer-textured soils and are found where water availability is reliable (Parrish & Fike 2005).

Both switchgrass ecotypes have been investigated as a REC (Parrish & Fike 2005); however, most research has focused on lowland varieties due to their higher yield potential. Yield varies greatly depend on many factors including ecotype, variety, geographic location, environmental conditions, fertilization, and management (Parrish & Fike 2005). Reported average annual mature stand yields are 10.3 Mg per hectare across the United States (Wullschleger et al. 2010), 16 Mg per hectare in the Midwest (McLaughlin & Walsh 1998), and 14.2 Mg per hectare in the Southeast (Fike et al. 2006).

As mentioned above, lowland varieties tend to produce more biomass compared to upland varieties. For instance, Fike et al. (2006) reported average yields for lowland varieties at 15.8 Mg per hectare, while upland cultivars averaged 12.6 Mg per hectare in the Southeast, and Wullschleger et al. (2010) reported average upland variety yields of 8.7 Mg per hectare and lowland variety yields of 12.9 Mg per hectare across the United States. However, if the stand is managed for forage and as a REC, upland varieties may provide a better dual purpose choice.

Switchgrass stands managed as RECs are typically a one-cut system (one- and two-cut systems of lowland varieties typically produce similar yields) harvested at 15 to 20 centimeters height using conventional haying equipment in the late-fall after a killing freeze (Parrish & Fike 2005). Less nitrogen and other nutrients are removed from the system when the material is allowed to senesce and retranslocate nutrients back into the roots for winter storage (Fike et al. 2006). Stubble maintenance results in soil, yield, and longevity benefits (Fargione et al. 2009). The higher stubble height may also reduce the incidents of tire blow-outs when equipment is in the field.

No-till establishment practices are recommended in order to avoid the germination of weed seed in the soil (Jensen et al. 2007). Switchgrass seed can be planted once soil temperatures reach 55°F, and there is a low risk of frost. During the establishment year, switchgrass is not expected to produce much aboveground biomass, because the plants are primarily establishing the extensive root system (Parrish & Fike 2005). Leaf and stem growth may only reach two feet by the end of the first growing season. By the second growing season, stands produce noticeably more aboveground biomass and should reach optimum yields by the third growing season. Switchgrass stand longevity varies by site, but it is not uncommon for stands to last over 10 years (Jensen et al. 2007, Fike et al. 2006).

The United States tallgrass prairie is among the most converted and one of the rarest biomes in the world (Fletcher et al. 2010, Payne & Caire 1999, Samson & Knopf 1994) with only 10% of the original 57 million hectares remaining (Payne & Caire 1999). During European settlement, a large portion of the native prairie habitats were replaced with non-native cool-season grasses (Blanco-Canqui 2010) or converted to row crop agricultural production (Blanco-Canqui 2010, Moulton et al. 1981). Most of the remaining tallgrass prairies are fragmented and exist along highways, railways, and cemeteries (Payne & Caire 1999). Overall, many wildlife species have been extirpated from their original inhabited areas, which resulted in changes in abundance and distribution patterns of many species (Kaufman et al. 2000, Paine et al. 1996).

Switchgrass stands have been established, mostly as a result of the USDA-NRCS Conservation Reserve Program (CRP) (Blanco-Canqui 2010, Fletcher et al. 2010, Fargione et al. 2009, McLaughlin & Walsh 1998), to increase wildlife habitat and conserve and improve soil and water resources (Blanco-Canqui 2010, Fargione et al. 2009, Hall & Willig 1994) by converting highly erodible cropland to native, perennial cover (Hall & Willig 1994). Jensen et al. (2007) showed that farmers are willing to establish switchgrass as a REC as long as they have assistance and information concerning production. Farmers showed specific interest in producing switchgrass to provide habitat for wildlife (Jensen et al. 2007).

Many researchers claim switchgrass stands managed as a REC may provide viable habitat for wildlife (McLaughlin & Walsh 1998, Tolbert & Wright 1998, Paine et al. 1996), yet little research has been conducted to defend this statement (Fletcher et al. 2010). Fletcher et al. (2010) published a review article on the biodiversity effects of land-use change to biofuel crops and found no investigations regarding biodiversity in biomass switchgrass compared to other land uses. They noted the importance of better understanding the biodiversity in switchgrass due to its importance as a second-generation biofuel crop.

Habitat characteristics of switchgrass stands managed for biomass that may positively influence the wildlife habitat quality are: a dense canopy cover that provides protection from predators, an open understory allowing good connectivity, and abundant seed and vegetation for food. Strategic placement and proper management of the stands can further enhance the positive attributes for wildlife (Fletcher et al. 2010). However, there are three characteristics of switchgrass biomass stands that may limit the wildlife habitat quality. These stands are typically managed as monocultures established at a high planting density and are annually harvested. Biodiversity of many wildlife species have been shown to be positively correlated with vegetative heterogeneity; thus, monocultures typically provide habitat for a smaller number of species than a more diverse plant community (Germano & Lawhead 1986). Additionally, Olson & Brewer (2003) stated that monotypic plantings provide little wildlife habitat value. The high planting density could limit accessibility and mobility for some wildlife species, and the late-fall harvest reduces protective winter cover (Olson & Brewer 2003). However, Murray & Best (2003a) claimed that the fall/winter harvest is better than a summer harvest, because it avoids the breeding season of many grassland birds.

Currently, published research has primarily focused on the wildlife habitat quality of switchgrass stands for grassland birds due to the rapidly declining populations in North America (Farrand & Ryan 2005, Murray et al. 2003b, Giuliano & Daves 2002, McCoy et al. 2001). This decline is thought to be a result of changing agricultural practices, including more frequent and earlier harvesting of pastures and hay fields, increased pesticide use, increased row crop production, increased homogeneous agricultural land area, and a decline in grassland production (Giuliano & Daves 2002, Best et al. 1997). Murray et al. (2003b) and Best et al. (1997) compared grassland bird populations in switchgrass stands compared to agricultural crop lands. Murray et al. (2003b) researched the potential effects of converting marginal crop lands to switchgrass stands managed for biomass production, while Best et al. (1997) compared switchgrass stands enrolled in the CRP and agricultural crop land in the Midwest. Murray et al. (2003b) reported a higher abundance of all bird species that are of conservation concern in the switchgrass biomass stands compared to agricultural row crops. Best et al. (1997) reported similar numbers of bird species in CRP enrolled switchgrass compared to row crops, but the switchgrass habitat had a higher abundance of birds and nests.

Little research has investigated mammals and other vertebrate groups in switchgrass REC systems (Farrand & Ryan 2005). Small mammals provide many ecosystem services in prairie ecosystems (Nickel et al. 2003). Some of the ecosystem services are predation of insect pests (Elliott & Root 2006, Stallman & Best 1996, Getz & Brighty 1986, Johnson 1986, Fleharty & Navo 1983) and weed seeds (Menalled et al. 2000, Cromar et al. 1999, Marino et al. 1997, Stallman & Best 1996, Getz & Brighty 1986, Johnson 1986, Fleharty & Navo 1983), seed dispersal (Elliott & Root 2006), nutrient cycling (Elliott & Root 2006, Stallman & Best 1996), soil structure improvement through the construction of burrows (Elliott & Root 2006, Fleharty & Navo 1983), and being a vital food source for avian, reptilian, and mammalian predators (Jacob 2003, Olson & Brewer 2003, Pinkert et al. 2002, Hines 1995). Due to the general life characteristics of small mammals, like small home-range, short dispersal distance, short life span, high reproductive rate, and generalized food use, they can be used as ecological indicators to assess the relative habitat quality of switchgrass biomass stands compared to other common land uses like hay and corn fields (Corry 2004). Restoration successes are frequently based on fluctuations in species richness and relative abundance of resident populations (Hall & Willig 1994). Species richness is used to assess disturbance effects, while changes in relative abundance are used as an environmental indicator of stress or release from stress (Hall & Willig 1994). Small mammals are sensitive to habitat disturbances and stress (Olson & Brewer 2003) and can quickly respond by migrating into and out of suitable and unsuitable habitats (Leis et al. 2008).

The objective of this study was to investigate the small mammal populations in switchgrass stands managed as a REC compared to other common land uses, specifically hay and corn fields, in order to assess the relative habitat quality of the REC switchgrass stands.

CHAPTER II: Literature Review

Small Mammal Species of Interest

The small mammal species of interest covered in this review are the white-footed mouse (*Peromyscus leucopus* (Refinesque)), prairie deer mouse (*Peromyscus maniculatus bairdii* (Hoy and Kennicott)), house mouse (*Mus musculus* (L.)), meadow vole (*Microtus pennsylvanicus* (Ord)), and prairie vole (*Microtus ochrogaster* (Wagner)) of the order Rodentia, and the northern short-tailed shrew (*Blarina brevicauda* (Say)) of the order Insectivora. Rodents are the most numerous mammals in abundance and species in Kentucky (Barbour & Davis 1974). These six species are considered generalist species, since they can survive in a wide range of habitats and conditions (Elliott & Root 2006, Block et al. 1999).

White-footed mice have a total length of 156-205 mm, tail length of 63-97 mm, hind foot length of 19-22 mm (Barbour & Davis 1974), ear length of 16-20 mm, and weigh 15-28 g (Reid 2006). The adult fur has three distinct colors: the top of the back is dark brown, the sides are orange-brown, and the underside is white with barely visible gray roots (Reid 2006). The tail is bicolored and lightly haired with a tuft of fur at the end two to three mm in length (Reid 2006). White fur covers the top of the four feet. Juvenile fur is gray and subadult fur has variations of gray to the adult coloration. The identifying characteristics are the long tail, white hind feet that are greater than 18 mm with a conformation for terrestrial movement and climbing, and the distinct tri-colored fur. They consume a variety of foods including insects, seeds, nuts, fruit, and green vegetation (Reid 2006, Barbour & Davis 1974, Whitaker 1966). They do not have a preference for agricultural crops such as corn and wheat (Block et al. 1999, Whitaker 1966). White-footed mice are nocturnal (Block et al. 1999, Barbour & Davis 1974), both terrestrial and arboreal (Reid 2006), and are active year-round (Barbour & Davis 1974). White-footed mice do not construct runways, but move in a ricochetal pattern with short hops and constant change of direction (Schramm & Willcutts 1983, Barbour & Davis 1974). They have a home range of 0.081 hectares and a dispersal distance of 430 meters (Corry 2004). White-footed mice typically nest aboveground (Reid 2006, Block et al. 1999, Barbour & Davis 1974), but occasionally nest on the ground in a sheltered area (Barbour & Davis

1974). They create spherical nests about 150-250 mm in diameter constructed of soft material where they raise their young (Reid 2006, Barbour & Davis 1974). White-footed mice mainly breed in the spring and fall (Reid 2006) from March through October (Barbour & Davis 1974, Wegner & Merriam 1990). The gestation period is ~25 days (Barbour & Davis 1974), and the typical litter size ranges from 3-6 young (Reid 2006, Barbour & Davis 1974) with females reproductively mature at 10 weeks old (Barbour & Davis 1974). The usual life span in the wild is less than a year (Reid 2006).

White-footed mice are positively associated with vertical heterogeneous habitat, often with woody vegetation (Kaufman et al. 2000, Clark et al. 1987). Kaufman et al. (2000) reported white-footed mice inhabiting woodlands over herbaceous vegetation and Sietman et al. (1994) reported a preference of habitats with woody vegetation over native tallgrass prairie. On the contrary, Clark et al. (1987) captured a high abundance of white-footed mice in tallgrass prairie habitat. White-footed mice are widespread and abundant across Kentucky (Barbour & Davis 1974) and the United States (Reid 2006).

Prairie deer mice have a total length of 116-154 mm, tail length of 40-58 mm, hind foot length of 17-20 mm (Barbour & Davis 1974), ear length of 16-21 mm (Reid 2006), and weigh 16-26 g (Barbour & Davis 1974). The adult fur is dark brown on the back, lighter brown on the sides, and white on the belly with some visible gray roots (Reid 2006). The tail is clearly bicolored with gray on top and white on the underside (Barbour & Davis 1974) and lightly haired with a tuft of fur at the end 4-5 mm in length (Reid 2006). Juvenile fur is gray and subadult fur has variations of gray to the adult coloration. The identifying characteristics are the distinct bicolored tail and white feet that are less than 18 mm with a conformation for terrestrial movement. They are opportunistic omnivores (Clark & Young 1986) that forage on the ground (Getz & Brighty 1986) and consume mainly seeds (Barbour & Davis 1974) like wheat, soybeans, weed seeds (Whitaker 1966), and corn (Block et al. 1999). They will also eat lepidopterous larvae (Whitaker 1966), other insects, fruit, and subterranean fungi (Reid 2006). Prairie deer mice are nocturnal (Barbour & Davis 1974), terrestrial (Reid 2006), and active year-round (Barbour & Davis 1974). They are solitary during the warm months and huddle in groups during the winter (Reid 2006, Barbour & Davis 1974). Prairie deer mice do not construct runways (Schramm & Willcutts 1983). They move by running and hopping across the ground (Schramm & Willcutts 1983, Barbour & Davis 1974). They have a home range of 0.6 hectares and a dispersal distance of 500 meters (Corry 2004). Prairie deer mice nest on the ground (Barbour & Davis 1974), in underground burrows, or in protected areas such as a hollow log (Reid 2006). They create nests up to 250 mm in diameter made of plant material and lined with soft material (Barbour & Davis 1974). Prairie deer mice breed year-round in mild climates and seasonally in areas with harsh winters (Reid 2006, Barbour & Davis 1974). The gestation period is 22-27 days and the litter size typically ranges from 3-6 young (Barbour & Davis 1974) with females reproductively mature at 46 to 51 days old (Barbour & Davis 1974).

Prairie deer mice occupy many different areas and are considered habitat generalists (Elliott & Root 2006, Block et al. 1999). They do not rely on herbaceous ground cover for protection, but rather create extensive burrow systems for protection (Stallman & Best 1996, Fleharty & Navo 1983). As a result, they often inhabit areas with minimal vegetative cover like agricultural crop lands (Clark & Young 1986) and are negatively associated with litter cover and depth (Kirsch 1997). Kaufman et al. (2000) reported that deer mice often inhabit herbaceous vegetation over woodlands. In Kentucky, they occupy crop land, grasslands, weed fields (Barbour & Davis 1974), and fence rows (Block et al. 1999). They are most common in the west and central areas of the state and are absent from the southeastern mountains and surrounding regions of the Cumberland Plateau (Barbour & Davis 1974). In the United States, they are abundant and widespread except in the Southeast and eastern region of Texas occupying many habitat types including boreal forest, tundra, desert, prairies, swamps, and high mountains (Reid 2006).

House mice have a total length of 130-198 mm, tail length of 63-102 mm, hind foot length of 14-21 mm, ear length of 11-18 mm (Barbour & Davis 1974), and weigh 7-24 g (Reid 2006). The adult fur is gray-brown to yellow-brown with a slightly lighter underside (Reid 2006). The tail is long, brown, and appears naked (Reid 2006). The identifying characteristics are the long naked tail, large hairless ears, uniform coloring, and musky odor (Reid 2006). House mice are opportunistic and will take advantage of any resources available (Barbour & Davis 1974). They consume grain, various seeds, corn, wheat, soybeans, and insects (Reid 2006, Whitaker 1966), as well as anthropogenic foods like flour and food scraps when occupying human dwellings (Barbour & Davis 1974). They are nocturnal (Reid 2006, Barbour & Davis 1974), mainly terrestrial but can climb (Reid 2006), and are active year-round (Reid 2006). They nest in underground burrows and sheltered areas in human dwellings like drawers and walls (Reid 2006). They construct loosely made nests of soft available materials (Barbour & Davis 1974). House mice breed year-round with females reproductively mature at 7-8 weeks old (Barbour & Davis 1974), and are capable of producing 13 litters in one year (Barbour & Davis 1974). The gestation period is 18-19 days (Barbour & Davis 1974) and the typical litter size ranges from 3-10 young (Barbour & Davis 1974).

The house mouse is an introduced species originating in Asia (Reid 2006, Kaufman & Kaufman 1990). House mice inhabit agricultural crop land, roadsides, (Reid 2006), other disturbed habitat (Kirsch 1997), and human dwellings (Reid 2006, Kirsch 1997, Barbour & Davis 1974). House mice are commonly captured in crop lands (Kaufman et al. 2000, Kirsch 1997) and tend to avoid grasslands (Kaufman et al. 2000, Kirsch 1997, Kaufman & Kaufman 1990) and woodlands (Kaufman et al. 2000, Kaufman & Kaufman 1990, Barbour & Davis 1974). They are common and widespread throughout Kentucky and the United States (Reid 2006, Barbour & Davis 1974).

Meadow voles have a total length of 140-195 mm, tail length of 32-64 mm, hind foot length of 18-24 mm (Barbour & Davis 1974), ear length of 13-16 mm, and weigh 22-66 g (Reid 2006). The adult fur is dark brown to bright chestnut with a silvery gray belly (Barbour & Davis 1974). The tail is relatively long, lightly haired, and slightly bicolored (Reid 2006). The identifying characteristics are the relatively long tail, silvery gray belly, fur that is not grizzled, and 6 pads on the soles of the hind foot (Reid 2006). They consume a variety of plant material, bark, roots, tubers, grain, seeds (Reid 2006, Barbour & Davis 1974) and fruit (Barbour & Davis 1974). Meadow voles are active day and night (Reid 2006, Barbour & Davis 1974), but peak in activity at six to seven in the morning and four to six in the evening (Blair 1948). They navigate the habitat safely by constructing runways ~40 mm wide under the litter (Barbour & Davis 1974). They can also swim, but do not climb (Reid 2006). Meadow voles have a home range of 0.04 hectares and a dispersal distance of 280 meters (Corry 2004). They nest aboveground or in a shallow burrow (Reid 2006, Barbour & Davis 1974) where they construct a 150 mm wide spherical nest made of dry grass with the inside lined with soft materials (Barbour & Davis 1974). Meadow voles are highly prolific and breed year-round (Reid 2006); however, they breed March through November in areas with harsh winters (Reid 2006). The gestation period is 21 days (Barbour & Davis 1974) and the litter size ranges from 1-11 young (Reid 2006). The females are reproductively mature at 25 days old (Barbour & Davis 1974) and can have as many as 13 to 17 litters a year (Barbour & Davis 1974).

Meadow voles inhabit roadside ditches, fencerows, damp meadows, orchards, prairies, and other habitats with dense vegetation (Reid 2006, Barbour & Davis 1974). Meadow voles require dense vegetation and a well-developed litter layer, because they construct runways under the cover (Sietman et al. 1994) for protection from predators (Hines 1995) and safe access to food (Lemen & Clausen 1984). Meadow voles regularly patrol their runways keeping them clear of debris (Barbour & Davis 1974). Lemen & Clausen (1984) reported a positive association between vole abundance and vegetation density. In Kentucky, meadow voles are abundant in the Inner and Outer Bluegrass region and eastward (Barbour & Davis 1974). In the United States, meadow voles inhabit the north and central regions, as well as Alaska (Reid 2006).

Prairie voles have a total length of 130-172 mm, tail length of 24-41 mm, hind foot length of 17-22 mm, ear length of 11-15 mm, and weigh 22-66 g (Barbour & Davis 1974). The adult fur is grizzled gray, gray-brown, or dark brown (Reid 2006, Barbour & Davis 1974) with a buff, cream, or grayish white belly (Reid 2006). The lightly haired tail is relatively short, clearly bicolored, and has a tuft of hair at the tip (Reid 2006, Barbour & Davis 1974). The identifying characteristics are the relatively short tail, grizzled fur, buff underbelly, and 5 pads on the soles of the hind foot (Reid 2006). They consume a variety of plant material, roots, tubers, (Reid 2006, Barbour & Davis 1974), bark, stems, grain, seeds, fruit (Barbour & Davis 1974), and insects (Hines 1995). Prairie voles are mainly active during the day and periodically during the night with the most activity at dawn and dusk (Reid 2006, Barbour & Davis 1974). They also construct runways to navigate the habitat, but they nest in underground burrows in nests made of dry grass (Barbour & Davis 1974). Prairie voles have a home range of 0.05 hectares and a dispersal distance of 320 meters (Corry 2004). Interestingly, prairie voles form monogamous pairs where both parents care for the young, as well as older offspring from previous litters

(Reid 2006). Prairie voles are capable of breeding all year long if conditions allow (Reid 2006, Barbour & Davis 1974), but most of the breeding occurs during the summer (Reid 2006). The gestation period is 21 days and the litter size is typically 1-9 young (Barbour & Davis 1974). Females usually have 3 to 4 litters per year (Barbour & Davis 1974). The females are reproductively mature at 30 days old (Barbour & Davis 1974).

Prairie voles inhabit prairies, grasslands, and agricultural lands (Reid 2006). They are mainly associated with grass-dominated habitats (Sietman et al. 1994) and prefer areas with a moderate to sparse amount of litter (Kaufman & Kaufman 2008). Prairie voles have expanded their historical range in Kentucky by utilizing tall fescue dominated pastures and hay fields and are now abundant statewide (Barbour & Davis 1974). They are common and widespread in the prairie states of the United States (Reid 2006).

The northern short-tailed shrew, the largest shrew in North America (Reid 2006), has a total length of 95-134 mm, tail length of 17-30 mm, hind foot length of 10-17 mm, and weighs 15-30 g (Barbour & Davis 1974). Like other shrews, northern short-tailed shrews have small eyes, a pointed nose, and ears concealed with fur (Barbour & Davis 1974). The adult fur is silvery gray to dark charcoal gray on the back and the underside is a lighter shade of the top (Reid 2006). The tail is short, slightly bicolored, and has a tuft of hair at the tip (Reid 2006). The identifying characteristics are the short tail, tiny eyes, barely visible ears, long snout, velvety textured charcoal colored fur, and a very strong musky odor. They are primarily carnivorous consuming insects, worms, snails, sowbugs (Reid 2006, Barbour & Davis 1974), centipedes, millipedes, and spiders (Barbour & Davis 1974). Northern short-tailed shrews have poisonous saliva (Reid 2006, Barbour & Davis 1974), which allows them to also consume salamanders, ground-nesting birds (Barbour & Davis 1974), and mice (Reid 2006, Barbour & Davis 1974). A fraction of the diet is vegetative matter including seeds (Reid 2006, Barbour & Davis 1974), fruits, roots, nuts, and acorns (Barbour & Davis 1974). They are active year-round during the day and night (Reid 2006). They are mainly terrestrial but will climb for food if necessary (Barbour & Davis 1974). Northern short-tailed shrews construct elaborate runways and burrow systems to safely navigate the habitat in search of food (Reid 2006, Barbour & Davis 1974). Northern short-tailed shrews have a home range of 0.59 hectares and a dispersal distance of 60 meters (Corry 2004). Nests are constructed in the burrows to raise young (Reid 2006). They breed February through September (Reid 2006). The gestation period is 21 or 22 days and the litter size is typically three to seven young (Reid 2006) with a (Barbour & Davis 1974). Females are capable of reproducing at seven weeks old (Reid 2006). The usual life span in the wild is less than a year (Reid 2006).

Northern short-tailed shrews inhabit hardwood and pine forests, borders of ponds, grasslands (Reid 2006), brush land, fencerows, weed fields, and dense pasture (Barbour & Davis 1974). They prefer moist areas with dense vegetation and a deep litter layer (Kirsch 1997). They are abundant throughout Kentucky (Barbour & Davis 1974) and are found in the northeast and north central United States (Reid 2006).

Population abundance patterns vary among the different species of interest. Prairie deer mice and white-footed mice populations exhibit seasonal fluctuations, and meadow voles and prairie voles undergo seasonal and multi-year population cycles (Reid 2006). Northern short-tailed shrew populations do not undergo predictable fluctuation patterns, but remain at low, uniform numbers (Blair 1948). Mice populations are low in the spring, and steadily increase during the summer with peak population abundance in the fall (Taitt & Krebs 1983, Stickel 1979). The fluctuations are due to the differences between birth and death rates (Wegner & Merriam 1990). Blair (1948) reported no significant differences in death rates between the four seasons with the chances of survival equal throughout the year; therefore, the change in population density reflects the breeding seasons with population increases during the breeding season and decreases when there is a lack of breeding. Vole populations experience a cyclical abundance pattern with some seasonal changes similar to mice populations (Blair 1948). Vole populations peak every 2-5 years followed by a population crash (Blair 1948).

The home ranges of these species overlap in some regions. The species richness and relative abundance of small mammals located in the same area are impacted by vegetation, soil characteristics, and species interactions (Sietman et al. 1994). Interspecies competition varies between the species of interest. Meadow voles and prairie voles segregate when occupying the same area with prairie voles inhabiting the upland, dry habitats (Moulton et al. 1981, Barbour & Davis 1974) and meadow voles in the lowland, moist dense habitats (Kirsch 1997, Barbour & Davis 1974). Prairie deer mice and white-footed mice are separated by habitat preference and competition (Whitaker 1967). Prairie deer mice and voles, prairie and meadow voles, segregate according to habitat preferences with prairie deer mice preferring poorly covered areas and voles occupying more dense vegetation (Whitaker 1967, Blair 1948). Prairie deer mice are also nocturnal and voles are more active during the day (LoBue & Darnell 1959). White-footed mice and prairie voles separate by habitat preference with white-footed mice in wood lands and prairie voles in grasslands (Whitaker 1967). When occupying the same area, they separate by niche differences and do not directly compete for resources (Whitaker 1967). House mice and prairie deer mice have an adverse relationship (Stallman & Best 1996, Fleharty & Navo 1983) possibly because both species inhabit disturbed and cultivated habitats (Whitaker 1967). White-footed mice out-compete house mice when in the same area (Whitaker 1967).

Small Mammals in Switchgrass and Tallgrass Prairie

Currently, there is no published work investigating small mammal populations in switchgrass stands managed as a REC. Fletcher et al. (2010) published a review on the biodiversity effects of land-use change to biofuel crops, and did not report any publications comparing the biodiversity of switchgrass managed for biomass and other land uses. However, small mammal populations have been studied in tallgrass prairies with switchgrass present as a dominant and non-dominant grass species in the habitats. Even though no research has studied switchgrass habitats with an annual late-fall harvest, mowing and haying effects have been researched on tallgrass prairie habitats. Historical tallgrass prairie systems were controlled by climate, specifically drought, coupled with periodic disturbance by fire and grazing by bison (Payne & Caire 1999, Samson & Knopf 1994). The primary objective of the mowing and haying research was to determine if these controlled, anthropogenic disturbance achieved effects similar to the original disturbances. This research may also be used to assess the potential effects of an annual harvest in switchgrass stands managed for biomass production.

Lemen & Clausen (1984) investigated the effects of mowing on small mammals in a native tallgrass prairie in eastern Nebraska. Meadow voles, prairie voles, western harvest mice (*Reithrodontomys megalotis* (Baird)), and deer mice were captured in the habitat prior to mowing (Table 2.2). Mowing significantly reduced the vegetative cover of the habitat and caused species-specific effects with deer mice responding positively, vole species (*Microtus* spp.) responding negatively, and western harvest mice showed no response (Lemen & Clausen 1984). In the same study, vole populations decreased while prairie deer mice increased due to the change in vegetative cover caused by mowing (Lemen & Clausen 1984). Birney et al. (1976) proposed the idea of a minimum threshold level of vegetative cover needed by voles to successfully survive and increase in abundance. Therefore, mowing may have reduced the vegetative cover below the necessary threshold and caused a decline in population. Deer mice may have immigrated to the habitat due to the lower vegetative cover or immigrated due to the reduced competition from voles (Lemen & Clausen 1984). LoBue & Darnell (1959) reported a similar interaction between voles and deer mice in a harvested alfalfa field in Wisconsin.

Switchgrass biomass stands are typically managed as a one-cut system harvested during the late-fall after a killing frost (Parrish & Fike 2005). A late-fall harvest greatly reduces the amount of winter cover and seed availability for small mammals by removing the standing, mature vegetation and litter at a time when regrowth will not occur again until the following spring (Kaufman & Kaufman 2008). Since most of the vegetation and some of the litter is removed, soil debris tends to be less in harvested stands compared to unharvested stands (Kaufman & Kaufman 2008). Kaufman and Kaufman (2008), Kaufman et al. (2000), and Sietman et al. (1994) investigated the harvesting effects of small mammals in tallgrass prairie habitat in Kansas. Kaufman and Kaufman (2008) and Kaufman et al. (2000) studied hay fields harvested in the summer/autumn time period (specific dates not available), while Sietman et al. (1994) studied fields harvested in mid-July. All three studies reported negative effects from haying tallgrass prairie habitat on small mammal populations. Kaufman and Kaufman (2008) and Kaufman et al. (2000) reported lower species richness and abundance in the hayed habitat. Kaufman and Kaufman (2008) captured 26 individuals of four species (deer mouse, prairie vole, western harvest mouse, and Elliot’s short-tailed shrew (*Blarina hylophaga* (Elliot)) in the hayed field compared to 115 individuals of nine species (deer mouse, prairie vole, western harvest mouse, Elliot’s short-tailed shrew, hispid cotton rat (*Sigmodon hispidus* (Say & Ord)), white-footed mouse, southern bog lemming (*Synaptomys cooperi* (Baird)), least shrew (*Cryptotis parva* (Say)), and eastern woodrat (*Neotoma floridana* (Ord)) in the control plots. Kaufman et al. (2000) captured 114 individuals of four species (deer mouse, prairie vole, hispid pocket mouse (*Chaetodipus hispidus* (Baird)), and northern grasshopper mouse (*Onychomys leucogaster* (Wied-Neuwied)) in the hayed field compared to 155 individuals of seven species (deer mouse, prairie vole, white-footed mouse, western harvest mouse, hispid cotton rat, and Elliot's short-tailed shrew) in the control plots. Sietman et al. (1994) reported no change in species richness, but the unharvested habitat had a higher relative abundance. Six species were captured in the hayed and unharvested fields with five of the six species the same (both habitats: deer mouse, prairie vole, hispid cotton rat, Elliot's short-tailed shrew and plains pocket gopher (*Geomys bursarius* (Shaw)); hay only: hispid pocket mouse; native only: western harvest mouse). In the hayed habitat, western harvest mice, Elliot's short-tailed shrews (Kaufman & Kaufman 2008), southern bog lemmings, least shrews, eastern woodrats (Kaufman et al. 2000), and prairie voles (Kaufman & Kaufman 2008, Kaufman et al. 2000) were uncommon, white-footed mice and hispid cotton rats were not present, and prairie deer mice were more common (Kaufman & Kaufman 2008). The negative effects associated with harvest may be due to the reduction of canopy cover from the removal of vegetation and litter and the loss of vertical structure diversity (Kaufman & Kaufman 2008, Sietman et al. 1994).

Monoculture switchgrass stands may have habitat characteristics similar to native tallgrass prairies since switchgrass is a native species of the ecosystem; however, it may lack the vertical and horizontal heterogeneity found in a diverse prairie. Studies investigating small mammals in tallgrass prairies with and without switchgrass listed as a dominate grass could be used to assess the potential habitat quality of switchgrass stands managed for biomass (Table 2.1 and 2.2).

Table 2.1 Species richness of small mammals and botanical species composition of tallgrass prairies with switchgrass listed as a dominant grass and the state where they were located.

Reference(s)	Location-Site	Species Richness of Small Mammal	Botanical Species Composition
Birney et al. 1976	OK	11	*Andropogon gerardii* (Vitman), *Panicum virgatum* (L.), *Schizachyrium scoparium* ((Michx.) Nash)
Clark et al. 1998	OK-upland prairie	6	*Andropogon gerardii, Andropogon virginicus* (L.), *Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans* ((L.) Nash), forbs
Clark et al. 1998	OK-lowland prairie	6	*Andropogon gerardii, Andropogon virginicus, Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans,* forbs
Grant & Birney 1979	OK	10	*Andropogon gerardii, Panicum virgatum*
Kaufman et al. 2000	KS-PG	7	*Andropogon gerardii, Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans,* forbs
McMillan et al. 1999; Clark et al. 1987	KS-Konza prairie	15	*Andropogon gerardii, Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans,* forbs
Payne & Caire 1999	OK-prairie	13	*Andropogon gerardii, Elymus canadensis* (L.), *Elymus virginicus* (L.), *Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans, Sporobolus asper* ((P. Beauv.) Kunth), *Tripsacum dactyloides* ((L.) L.), forbs
Pinkert et al. 2002	SD	5	*Panicum virgatum*
Schramm & Willcutts 1983	IL	9	*Andropogon gerardii, Panicum virgatum, Sorghastrum nutans,* forbs
Sietman et al. 1994	KS-native	6	*Andropogon gerardii, Bouteloua curtipendula* ((Michx.) Torr.), *Dichanthelium oligosanthes* ((Schult.) Gould), *Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans, Sporobolus asper,* forbs
Sietman et al. 1994	KS-hayfield	6	*Andropogon gerardii, Aristida oligantha* (Michx.), *Bouteloua curtipendula, Dichanthelium oligosanthes, Eragrostis spectabilis* ((Pursh) Steud.), *Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans, Sporobolus asper,* forbs

Table 2.2 Species richness of small mammals and botanical species composition of tallgrass prairies with and without switchgrass listed as a dominant grass and the state where they were located.

Reference(s)	**Location-Site**	**Species Richness of Small Mammal**	**Botanical Species Composition**
Birney et al. 1976	OK	11	*Andropogon gerardii, Panicum virgatum, Schizachyrium scoparium*
Clark et al. 1998	OK-upland prairie	6	*Andropogon gerardii, Panicum virgatum, Schizachyrium scoparium*
Clark et al. 1998	OK-lowland prairie	6	*Andropogon gerardii, Andropogon virginicus, Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans,* forbs
Clark et al. 1998	OK-upland mowed prairie	6	*Andropogon gerardii, Andropogon virginicus, Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans,* forbs
Grant & Birney 1979	MN	8	*Andropogon gerardii, Andropogon virginicus, Schizachyrium scoparium,* forbs
Grant & Birney 1979	OK	10	*Poa pratensis* (L.), *Schizachyrium scoparium*
Kaufman & Kaufman 2008	KS	9	*Andropogon gerardii, Panicum virgatum*
Kaufman et al. 2000	KS-UG	6	*Andropogon gerardii, Schizachyrium scoparium, Sorghastrum nutans,* forbs
Kaufman et al. 2000	KS-PG	7	*Agropyron smithii* ((Rydb.) A. Löve), *Schizachyrium scoparium, Sporobolus* spp. (R. Br.), forbs
Kaufman & Fleharty 1974	KS-III,VI,VII	9	*Andropogon gerardii, Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans,* forbs
Kaufman & Fleharty 1974	KS-IV,V	4	*Andropogon gerardii, Bouteloua curtipendula, Schizachyrium scoparium*
Kaufman & Fleharty 1974	KS-VIII	6	*Andropogon gerardii, Bouteloua curtipendula, Schizachyrium scoparium*
Kirsch 1997	NE	8	*Andropogon gerardii, Aster ericoides* (L.), *Euphorbia corollata* (L.), *Melilotus officinalis* ((L.) Lam.), *Poa pratensis, Schizachyrium scoparium, Stipa spartina* (Trin.)
Lemen & Clausen 1984	NE	4	*Andropogon gerardii, Bouteloua* spp. (Lag.), *Koeleria cristata* ((Ledeb.) Schult.), *Schizachyrium scoparium, Stipa spartina, Sporobolus spp.,* forbs
McMillan et al. 1999; Clark et al. 1987	KS-Konza prairie	15	*Andropogon gerardii, Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans,* forbs
Moulton et al. 1981	CO-Yuma Site	8	*Bouteloua curtipendula, Schizachyrium scoparium,* forbs
Moulton et al. 1981	CO-Vilas Site	10	*Andropogon gerardii, Andropogon hallii* (Hack.), *Aristida* spp. (L.), *Artemisia filifolia* (Torr.), *Bouteloua curtipendula, Eragrostis trichodes* ((Nutt.) Alph. Wood), *Sporobolus cryptandrus* ((Torr.) A. Gray), forbs
Moulton et al. 1981	CO-Campo Site	5	*Artemisia filifolia* (Torr.), *Bouteloua curtipendula, Sporobolus cryptandrus,* forbs
Payne & Caire 1999	OK-prairie	13	*Andropogon gerardii, Elymus canadensis, Elymus virginicus, Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans, Sporobolus asper, Tripsacum dactyloides,* forbs

Table 2.2 (continued) Species richness of small mammals and botanical species composition of tallgrass prairies and the state where they were located.

Reference(s)	Location-Site	Species Richness of Small Mammal	Species
Pinkert et al. 2002	SD	5	*Panicum virgatum*
Schramm & Willcutts 1983	IL	9	*Andropogon gerardii, Panicum virgatum, Sorghastrum nutans,* forbs
Sietman et al. 1994	KS-native	6	*Andropogon gerardii, Bouteloua curtipendula, Dichanthelium oligosanthes, Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans, Sporobolus asper,* forbs
Sietman et al. 1994	KS-hayfield	6	*Andropogon gerardii, Aristida oligantha, Bouteloua curtipendula, Dichanthelium oligosanthes, Eragrostis spectabilis, Panicum virgatum, Schizachyrium scoparium, Sorghastrum nutans, Sporobolus asper,* forbs

Small Mammals in Hay

Few studies have investigated small mammal populations in hay fields dominated by cool-season grasses like tall fescue (*Lolium arundinaceum* ((Schreb.) Darbysh.)), Kentucky bluegrass (*Poa pratensis* (L.)), orchardgrass (*Dactylis glomerata* (L.)), and cool-season legumes, like alfalfa (*Medicago sativa* (L.)) and clovers (*Trifolium* spp. (L.)). Some research has studied mowing and harvesting effects on small mammal populations. Unfortunately, many publications omitted pertinent information, such as not describing the botanical species composition of the hay field (Wegner & Merriam 1990), discussing one small mammal species captured and not listing additional species (Peles & Barrett 1996, Edge et al. 1995), and combining all small mammal species into one category and not listing individual species (Washburn & Seamans 2007). Researchers also loosely use the term "grassland" without a clear description of the habitat to describe many different systems including native prairies and non-native planted systems.

Small mammal species richness varied in hay fields depending on location, management practices, and botanical composition. Peles & Barrett (1996) studied the importance of vegetative cover on meadow voles in harvested and unharvested fields dominated with fescue (*Festuca eliator* (L.)), timothy (*Phleum pratense* (L.)), red clover (*Trifolium pratense* (L.)), white clover (*Trifolium repens* (L.)), and alfalfa in Ohio. Additional species trapped were not reported. Stickel (1979) studied a hay field composed of orchardgrass and Korean lespedeza (*Lespedeza stipulacea* (Maxim.) Makino) in Maryland and captured 9 species: northern short-tailed shrew, least shrew, meadow vole, house mouse, white-footed mouse, prairie deer mouse, woodland vole (*Microtus pinetorum* (McMurtrie)), masked shrew (*Sorex cinereus* (Kerr)), and meadow jumping mouse (*Zapus hudsonius* (Zimmermann)). Edge et al. (1995) investigated the effects of mowing on the gray-tailed vole (*Microtus canicaudus* (Miller)) in an alfalfa field in Oregon. Additional species trapped were not reported. LoBue & Darnell (1959) studied the effects of harvesting an alfalfa field in Wisconsin. The thirteen-lined ground squirrel (*Spermophilus tridecemlineatus* (Mitchill)), meadow vole, house mouse, prairie deer mouse, woodland deer mouse (*Peromyscus maniculatus gracilis* (LeConte)), and meadow jumping mouse were captured in both the harvested and unharvested fields, while the northern short-tailed shrew, southern red-backed vole (*Clethrionomys gapperi*

(Vigors)), and masked shrew were captured only in the unharvested fields. Wegner & Merriam (1990) looked at various land uses (hay, pasture, corn, small cereal grain fields, fencerow, and small woodlot) on a farm in Ontario, Canada. The botanical composition of the hay field was not described, and only the white-footed mouse population dynamics were discussed. Additional species trapped were not made available.

Hay field management practices, specifically mowing and harvesting, impact small mammal populations due to the alteration of vegetative structure (Kaufman & Kaufman 2008). These disturbances also decrease vegetative cover (Edge et al. 1995, Zou et al. 1989, Lemen & Clausen 1984), food availability (Edge et al. 1995, Zou et al. 1989, Lemen & Clausen 1984), nesting material (Spencer et al. 2005), and protection from predators (Edge et al. 1995), as well as increase dispersion (Edge et al. 1995) and disrupts social organizations (Edge et al. 1995). Many of these effects are interconnected. For instance, predation risk and food availability are related to the amount of vegetation (Spencer et al. 2005).

Vegetative cover, which includes the standing crop and litter, is an important characteristic in habitat quality (Peles & Barrett 1996). Early in the growing season when the standing crop is short, litter is the most important component of cover. During the growing season, the standing crop provides increasingly more cover and litter becomes less important (Peles & Barrett 1996). Plant litter is minimal in harvested hay fields; thus not providing the important cover for small mammals early in the growing season (Kaufman & Kaufman 2008). Harvesting decreases the amount of vegetation in the short and long term. Kaufman & Kaufman (2008) found that grasslands harvested during the early summer were shorter by the end of the growing season than in grasslands that were not harvested. Hay fields harvested during the early summer had greater regrowth than fields harvested in the late summer (Kaufman & Kaufman 2008), but most hay fields are harvested multiple times during the growing season. Producers may harvest hay fields two to four times during the growing season depending on the environmental conditions. Hay fields harvested in the late summer or early autumn had little regrowth before winter dormancy. Therefore, there is little vegetative cover and food, both seeds and vegetation, for small mammals during the winter (Kaufman & Kaufman 2008).

Vegetative cover is specifically important for vole species and is a major factor in habitat selection (Peles & Barrett 1996). Vole populations are positively correlated with vegetative cover (Lemen & Clausen 1984, LoBue & Darnell 1959); thus, areas with plenty of cover tend to have higher populations (Peles & Barrett 1996, Taitt & Krebs 1983, Birney et al. 1976, Kaufman & Fleharty 1974). Voles respond positively to cover and litter, because they need the material to construct nests and runways (Peles & Barrett 1996), for food (Taitt & Krebs 1983), and for protection from predators (Hines 1995, Taitt & Krebs 1983).

There are two components of harvesting hay fields, mowing the stand and subsequently removing the cut material both of which effect small mammal populations. Barras & Carrara (2000) found that total abundance and species richness of small mammals was greater in unmowed areas compared to mowed areas (Barras & Carrara 2000). Total abundance also increased in unmowed areas, but stayed the same in mowed areas (Barras & Carrara 2000). Edge et al. (1995) reported a decline in survival rates, number of immigrants, and growth rates and an increase in the number of emigrants as a result of mowing. Mowing effects were reported as density independent, and therefore have the same impact on small mammals no matter the population size (Edge et al. 1995). Washburn & Seamans (2007) reported drastic differences with six species captured in an unmowed cool-season grassland and no captures in a mowed cool-season grassland.

However, mowing effects vary depending on species. Prairie deer mice (Slade & Crain 2006, Schauber et al. 1997) and white-footed mice (Slade & Crain 2006) were reported to not be adversely affected by mowing. On the other hand, gray-tailed voles (Schauber et al. 1997, Edge et al. 1995), prairie voles (Slade & Crain 2006), and Townsend's voles (*Microtus townsendii* (Bachman)) (Taitt & Krebs 1983) were less abundant in mowed habitats compared to unmowed controls. Vole populations did recover in some studies as the season progressed and vegetative cover was restored (Slade & Crain 2006, Edge et al. 1995). Edge et al. (1995) reported gray-tailed vole populations returning to original levels in enclosures, and Slade & Crain (2006) began to recapture prairie voles once the grasses and forbs recovered after they were eradicated in mowed plots.

Harvest, where the mowed vegetation is removed, has additional negative consequences, since the material is not left to accumulate as litter. Harvest effects also vary depending on species. Prairie deer mice were found in areas with little vegetative cover (LoBue & Darnell 1959), while meadow voles were found in areas with dense vegetative cover. LoBue & Darnell (1959) studied the reactions from these two species in a harvested alfalfa field. As the alfalfa field increased in vegetative cover during the growing season, prairie deer mice decreased in abundance while meadow voles increased. After harvest, prairie deer mice population increased and the meadow vole population declined. Lemen & Clausen (1984) reported the same interaction in a native tallgrass prairie habitat in Nebraska.

Research has also been conducted investigating small mammal populations in hay fields compared to other land uses. Stickel (1979) studied small mammal populations in a corn-wheat-hay rotation system. Nine species were captured in the hay field, but only white-footed mice, house mice, and meadow vole population dynamics were discussed in detail. The three species abundance over time followed a similar pattern: an increasing population during the growing season and then declining through the fall and winter. House mice were the most abundant in the hay field followed closely by meadow voles. White-footed mice were the least abundant species. However, white-footed mice and meadow voles were captured more in hay fields than corn and wheat fields. During the spring as vegetative cover became increasingly dense, house mice emigrated from the hay field to the wheat field, which caused a quick decrease in the hay field, but the population recovered over time with peak abundance in October. In contrast, the meadow vole population increased with the increasing vegetative density during the growing season, in addition to voles immigrating as a result of the wheat harvest. The primary cause of the population fluctuations and between habitats was due to migration (Stickel 1979). Wegner & Merriam (1990) investigated white-footed mice populations in hay, pasture, corn, barley, oats, spring wheat, fencerows, and woods. The hay habitat was the least used of all the land uses during the growing season, and was not utilized during the winter by any of the species (Wegner & Merriam 1990).

Studies have investigated management practices that may potentially reduce the negative impact from mowing and harvesting. Slade & Crain (2006) investigated the effects of strip-mowing hay fields early in the growing season on small mammal communities, and reported a quick vegetative regrowth and little impacts on small mammals. Changes in small mammal abundance and migration were small and returned to initial figures shortly after disturbance (Slade & Crain 2006). The mowed vegetation was not removed in this study (Slade & Crain 2006). Humbert et al. (2009) looked at the impacts of various harvesting equipment on small mammals, and found that cutter bar mowers resulted in half the amount of deaths compared to rotary and flail mowers. Kaufman & Kaufman (2008) recommends leaving a perimeter of undisturbed hay fields to be used as a refuge area for small mammals if harvesting the entire field is unavoidable.

Small Mammals in Corn

In the Midwest and Transition zones of the United States, farmland composes much of the land area, thus providing most of the available wildlife habitat (Pinkert et al. 2002, Stallman & Best 1996): 58% in the Midwest and 55% in Kentucky (United States 2007). In the Midwest, 78% of the farmland is in crop production and 52% in Kentucky (United States 2007). The conversion of land to agricultural production has resulted in fragmentation and elimination of natural habitats (Mankin & Warner 1999, Kirsch 1997), and therefore has been one of the most important wildlife impact factors in the United States (Mankin & Warner 1999).

Even so, little is known about the effects on small mammal wildlife distribution and abundance in agricultural land systems, since most research has focused on areas relatively undisturbed by human activity (Fleharty & Navo 1983). Plus, the research that has been conducted in agricultural systems has primarily investigated anthropogenic interests, such as potential economic damages and pest control methods (Fleharty & Navo 1983). More information is needed concerning species richness, abundance, distribution, and food preference of small mammals in various agricultural systems, as well as the effects of agricultural practices on population dynamics (Fleharty & Navo 1983).

In corn fields (*Zea mays* (L.)), small mammals can benefit agricultural producers by predating on insects, like grasshoppers, wireworms, earworms, and cutworms (Getz &

Brighty 1986, Johnson 1986, Holm 1984, Young 1984, Fleharty & Navo 1983, Whitaker 1966), waste grain (Getz & Brighty 1986, Johnson 1986), and weed seeds (Menalled et al. 2000, Cromar et al. 1999, Marino et al. 1997, Getz & Brighty 1986, Johnson 1986, Fleharty & Navo 1983), as well as improve the soil through the construction of burrows (Elliott & Root 2006, Fleharty & Navo 1983). Mice species, especially prairie deer mice, seem to be the most important weed seed predator in corn fields (Cromar et al. 1999) with prairie deer mice having the potential of consuming up to 64% of the average weed seed production (Getz & Brighty 1986). Prairie deer mice do not climb on stalks, and therefore only consume waste corn that has been left after harvest (Getz & Brighty 1986). House mice also consume weeds seeds, but half as much as prairie deer mice (Getz & Brighty 1986).

Conversely, small mammals can cause significant food loss of cultivated crops and stored products including sugarcane (*Saccharum officinarum* (L.)), rice (*Oryza sativa* (L.)), corn, wheat (*Triticum aestivum* (L.)), sorghum (*Sorghum* (Moench)), coconuts (*Cocos nucifera* (L.)), cacao (*Theobroma cacao* (L.)), cotton (*Gossypium* (L.)), peanuts (*Arachis hypogaea* (L.)), and soybeans (*Glycine max* ((L.) Merr.)) (Lord 1983). Three small mammal species have been reported as the primary species responsible for these damages: the brown rat (*Rattus norvegicus* (Berkenhout)), the black rat (*Rattus rattus* (L.)), and the house mouse (Lord 1983). Voles also cause damage and have been termed the most important vertebrate pest in agriculture for central Europe (Jacob 2003). However, few small mammal species have been termed pests in the United States (Fleharty & Navo 1983).

Previous research in corn systems has reported variable results concerning damage caused by small mammals. Multiple research studies have reported no damage to corn crops by small mammals and concerns over crop damage are generally viewed as unwarranted (Sterner et al. 2003, Stallman & Best 1996, Clark & Young 1986, Fleharty & Navo 1983, Getz & Brighty 1986). Some damage has been noted by deer (*Odocoileus* (Rafinesque)) and jack rabbits (*Lepus californicus* (Gray)) (Sterner et al. 2003). Clark & Young (1986) reported more damage to corn seedlings from insects and weather than by small mammals. Additionally, small mammals were found to more readily consume crop-damaging insects and weed seeds over corn seed (Clark & Young 1986); however, consumption of corn may occur in the early spring when insects are less abundant (Clark & Young 1986). Other research has reported damage to corn crops, primarily in no-till established fields (Hines 1995, Johnson 1986). Hines (1995) reported crop damage of newly planting stands as high as 80 to 100% loss by vole species when at high densities. Johnson (1986) reported potential stand losses of >25% in conservation-tillage corn fields during the first three weeks after planting, but the average stand loss was lower and variable. Prairie voles in no-till corn fields have been found to cause some crop losses in Illinois (Beasley & McKibben 1976). Overall, small mammal damage is variable among and within corn fields and varies annually (Johnson 1986).

Prairie deer mice have been reported in many studies as the most abundant species in corn fields, especially NT stands (Olson & Brewer 2003, Pinkert et al. 2002, Kirsch 1997, Stallman & Best 1996, Clark & Young 1986, Getz & Brighty 1986, Castrale 1985, Holm 1984, Warburton & Klimstra 1984, Young 1984). Other studies have reported corn fields as suitable habitat for prairie deer mice, but did not report a dominant role (Sterner et al. 2003, Block et al. 1999, Cromar et al. 1999, Williams et al. 1994, Fleharty & Navo 1983, Whitaker 1966). Prairie deer mice are opportunistic omnivores (Stallman & Best 1996, Clark & Young 1986) with the capability of utilizing more open, disturbed areas with minimum cover (Stallman & Best 1996, Barrett et al. 1990, Fleharty & Navo 1983, Whitaker 1966), due to their use of extensive burrow systems (Stallman & Best 1996, Fleharty & Navo 1983) which lowers the risk of predation (Stallman & Best 1996). White-footed mice and house mice have also been reported to reside in corn fields (Table 2.3). White-footed mice are commonly considered woodland species (Wegner & Merriam 1990); however, research has shown that some populations have adapted and expanded into agricultural systems (Wegner & Merriam 1990). Similar white-footed mice population densities have been reported in corn fields and woodlands (Wegner & Merriam 1990). Contradictory to other research, Albers et al. (1990) reported white-footed mice as the most abundant species and Stickel (1979) reported house mice as the most abundant in the corresponding corn fields. House mice also tolerate disturbed habitats, but they require more cover than prairie deer mice (Kirsch 1997). Table 2.3 illustrates small mammal species captured in NT and CT corn fields and the state in which they were found. Although multiple small mammals species have been found in corn fields many are not resident species and most were caught in few numbers. Prairie deer mice, white-footed mice, and house mice seem to be the only species that were caught in relatively high densities with prairie deer mice being the only resident species in many studies.

The investigation of corn field habitats incorporates a wide-variety of corn tillage systems. Most wildlife research has investigated potential differences between NT and CT systems because of the large contrast (Johnson 1986). No-till systems have minimal soil disturbance and high crop surface residues (Johnson 1986). By leaving surface residue, no-till systems reduce soil and water loss (Bilenca 2007, Sterner et al. 2003, Stallman & Best 1996, Johnson 1986), improve nutrient efficiency (Bilenca 2007), and increase soil organic matter, soil-moisture, and carbon and nitrogen retention (Sterner et al. 2003, Johnson 1986). Additional advantages of NT systems include fewer labor and energy inputs and higher, more stable yields (Bilenca 2007, Sterner et al. 2003, Johnson 1986). The presence of surface residues and the lack of tillage are beneficial for small mammals, because it allows the establishment of burrows (Sterner et al. 2003, Johnson 1986) and provides food and cover (Sterner et al. 2003, Johnson 1986, Warburton & Klimstra 1984). However, herbicide and insecticide use replaces tillage for weed and insect control (Albers et al. 1990, Johnson 1986), which may negatively affect small mammals (Warburton & Klimstra 1984).

Conventional tillage systems are tilled systems that leave <15% surface residue after planting, and involves plowing or other intensive tillage (United States 2000). Weeds are controlled with herbicides and cultivation (United States 2000). Conventional tillage systems may not provide viable wildlife habitat, because the system has little surface residue, low botanical diversity, often has periods of little or no vegetative cover, and field operations are frequent and may take place during the breeding season (Papendick & Elliott 1985). Caldwell (1986) also reported increased predation on small mammals by predatory birds, like red-tailed hawks (*Buteo jamaicensis* (J.F. Gmelin)) and American kestrels (*Falco sparverius* (L.)), in conventionally tilled corn fields. When fields are tilled small mammals are flushed from the area, which attracts predatory birds and increases the predation risk for small mammals (Caldwell 1986).

Research has reported NT systems as better habitat than CT corn fields (Warburton & Klimstra 1984) with a higher small mammal abundance (Warburton & Klimstra 1984), species diversity (Johnson 1986, Young 1984), and more stable populations (Johnson 1986, Warburton & Klimstra 1984). Prairie deer mice, in particular, were reported to have higher densities and less of a turnover; therefore, the population was more stable in NT fields compared to CT (Warburton & Klimstra 1984). Albers et al. (1990) also reported a higher abundance of white-footed mice in NT fields. On the contrary, other studies reported no adverse affects by tillage on resident small mammals (Albers et al. 1990, Wegner & Merriam 1990, Getz & Brighty 1986, Castrale 1985, Fleharty & Navo 1983) and CT corn fields provided viable habitat for many small mammal species (Fleharty & Navo 1983).

The annual grain harvest in corn systems is another important characteristic that influences small mammal populations. Research has shown that mice population densities, specifically prairie deer mice and house mice, are negatively affected by crop harvest (Pinkert et al. 2002, Williams et al. 1994, Stickel 1979). Prairie deer mice populations ultimately decrease as a result of harvest in corn fields (Pinkert et al. 2002, Williams et al. 1994); however, some studies report an initial increase then subsequent decline (Williams et al. 1994). This pattern is likely due to the increase in food abundance of waste corn which attracts mice to the area, and the subsequent decline may result from an increase in predation due to the lack of cover (Williams et al. 1994). The same study also reported house mice populations declining to zero two weeks after harvest even though corn waste grain remained present in the field (Williams et al. 1994). Stickel (1979) reported a similar occurrence of house mice populations continuing to decline after harvest even though corn stalks and weed debris were abundant and had not changed.

Table 2.3 Species and species richness of small mammals captured in no-till (NT) and conventionally tilled (CT) corn fields and the state where they were located.

Reference	**Location**	**Tillage**	**Species Richness of Small Mammal**	**Species**
Beasley & McKibben 1976	IL	NT	2	*Microtus ochrogaster* (Wagner), *Synaptomys cooperi* (Baird)
Block et al. 1999	IA	CT	2	*Peromyscus leucopus* (Refinesque), *Peromyscus maniculatus* (Wagner)
Castrale 1985	IN	NT	3	*Mus musculus* (L.), *Peromyscus leucopus, Peromyscus maniculatus*
Clark & Young 1986	IA	NT	2	*Peromyscus maniculatus, Spermophilus tridecemlineatus* (Mitchill)
Clark & Young 1986	IA	CT	2	*Peromyscus maniculatus, Spermophilus tridecemlineatus*
Fleharty & Navo 1983	KS	CT	9	*Dipodomys ordii* (Woodhouse), *Mus musculus, Onychomys leucogaster* (Wied-Neuwied), *Perognathus flavescens* (Merriam), *Perognathus hispidus* (Baird), *Peromyscus maniculatus, Reithrodontomys megalotis* (Baird), *Sigmodon hispidus* (Say & Ord), *Spermophilus spilosoma* (Bennett)
Holm 1984	NE	NT	10	*Blarina brevicauda, Dipodomys ordii, Microtus spp.* (Schrank), *Mus musculus, Onychomys leucogaster, Perognathus hispidus, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Spermophilus tridecemlineatus*
Olson & Brewer 2003	WY	N/A	3	*Onychomys leucogaster, Peromyscus maniculatus, Reithrodontomys montanus* (Baird)
Sterner et al. 2003	CO	NT	1	*Peromyscus maniculatus*
Stickel 1979	MD	CT	3	*Mus musculus, Peromyscus leucopus, Peromyscus maniculatus*
Warburton & Klimstra 1984	IL	CT	3	*Mus musculus, Peromyscus leucopus, Peromyscus maniculatus*
Warburton & Klimstra 1984	IL	NT	3	*Mus musculus, Peromyscus leucopus, Peromyscus maniculatus*
Whitaker 1966	IN	N/A	3	*Mus musculus, Peromyscus leucopus, Peromyscus maniculatus (bairdii)*
Young 1984	IA	NT	10	*Blarina brevicauda* (Say), *Microtus pennsylvanicus, Mus musculus, Onychomys leucogaster, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Sorex cinereus* (Kerr), *Spermophilus tridecemlineatus, Zapus hudsonius* (Zimmermann)

CHAPTER III: Materials and Methods

Study Area

My research was conducted in congruence with a study producing switchgrass as a REC on 20 farms in 12 counties in northeastern Kentucky. Two hectare monoculture plots of switchgrass were established using no-till establishment techniques at a planting density of 11.2 kilograms pure live seed (PLS) per hectare at each location: seven plots were established spring 2007 and 13 were established spring 2008. The plots were managed as a one-cut system harvested at a 15 to 20 centimeter height in the late-fall ~two weeks after a killing frost.

My study was conducted in 2009 on four of the farms included in the switchgrass project located in Fayette (Fayette farm), Lewis (Lewis farm), and Boyd counties (Boyd_N and Boyd_S farms) of Kentucky, USA. Plot area, elevation, and geographical coordinates are shown in Table 3.1.

Table 3.1 Geographical description of the corn (NT = no-till; CT = conventional till), hay, and switchgrass for each farm.

Farm	Habitat	Area (ha)	Elevation (m)	Latitude	Longitude
Boyd_S	Corn (CT)	5	200	38° 18’ 40’’	-82° 43’ 15’’
	Hay	6	200	38° 18’ 38’’	-82° 43’ 10’’
	Switchgrass (2 yrs old)	2	200	38° 18’ 44’’	-82° 43’ 8’’
Fayette	Corn (NT)	14	280	38° 7’ 15’’	-84° 30’ 17’’
	Hay	12	280	38° 7’ 58’’	-84° 29’ 54’’
	Switchgrass (3 yrs old)	2	280	38° 7’ 57’’	-84° 29’ 50’’
Lewis	Corn (CT)	8	260	38° 31’ 51’’	-83° 37’ 24’’
	Hay	8	200	38° 31’ 29’’	-83° 37’ 18’’
	Switchgrass (3 yrs old)	2	230	38° 31’ 26’’	-83° 37’ 19’’
Boyd_N	Corn (NT)	2	190	38° 20’ 8’’	-82° 43’ 0’’
	Hay	6	190	38° 20’ 19’’	-82° 43’ 2’’
	Switchgrass (2 yrs old)	2	190	38° 20’ 10’’	-82° 42’ 56’’

On each farm, one field of corn, hay, and switchgrass were selected in close proximity of each other to maintain similar environmental conditions. The Fayette and Lewis switchgrass stands were established spring 2007 (3 years old), and the Boyd_N and Boyd_S switchgrass stands were established spring 2008 (2 years old). Corn fields were managed for grain production with the Fayette and Boyd_N fields established with no field cultivation (NT) at 74,260 plants per hectare, and Boyd_S and Lewis fields were established with CT at 74,260 and 66,830 plants per hectare, respectively. Hay fields were perennial, cool-season forage stands >five years old and were harvested three times during the 2009 growing season. The planting and harvest dates of the three habitats for each farm are shown in Table 3.2.

Table 3.2 Planting and harvest dates of the corn (NT = no-till; CT = conventional till), hay, and switchgrass for each farm.

Farm	Habitat	Planting Dates	Harvest Dates		
Boyd_S	Corn (CT)	mid-May 2009			early-Nov 2009
	Hay	-	mid-May 2009	Aug 1, 2009	mid-Sept 2009
	Switchgrass (2 yrs old)	June 2008			Nov 10, 2009
Fayette	Corn (NT)	Apr 24, 2009			early-Nov 2009
	Hay	-	June 3, 2009	mid-July 2009	late-Aug 2009
	Switchgrass (3 yrs old)	June 2007			Nov 13, 2009
Lewis	Corn (CT)	late-April 2009			late-Nov 2009
	Hay	-	early-June 2009	late-June 2009	mid-Aug 2009
	Switchgrass (3 yrs old)	June 2007			Nov 9, 2009
Boyd_N	Corn (NT)	early-May 2009			late-Oct 2009
	Hay	-	late-May 2009	early-July 2009	early-Sept 2009
	Switchgrass (2 yrs old)	June 2008			Nov 10, 2009

Sampling Techniques

Farms were evaluated four times in 2009: Spring, before first hay harvest (Boyd_N and Boyd_S May 7-9; Lewis May 31-June 2; Fayette June 6-8); Summer (Fayette July 19-21; Boyd_N and Boyd_S July 27-29; Lewis August 13-15); Fall, before switchgrass and corn harvest (Fayette September 6-8; Boyd_N and Boyd_S October 2-4; Lewis October 11-13); and Winter, after switchgrass and corn harvest (Lewis December 4-6; Fayette December 10-12; Boyd_N and Boyd_S December 18-19). Each trapping session lasted three consecutive nights (weather permitting). Vegetative measurements were recorded at the conclusion of each session to determine habitat characteristics that may influence small mammal populations. Live-trapping methods generally followed procedures established in Larkin et al. (2008).

A 50 X 50 meter trapping grid with one Sherman live trap stationed every 10 meters was established in each field with a 20 m perimeter buffer zone to avoid edge effects. Traps were set one to two hours before sunset and checked one to two hours after sunrise the following morning. Traps were closed during the day to avoid unwanted casualties. Mixed birdseed was used as bait and cotton batting was added for bedding.

Each small mammal capture was identified to genus or species and the sex, weight, age class (juvenile/subadult/adult) and trap location was recorded. Weight was recorded using Pesola® 60 and 100 gram spring scales (Pesola© AG, Baar, Switzerland). Individuals were released at location of capture. The small mammal handling procedure was approved by the University of Kentucky Institutional Animal Care and Use Committee (IACUC) protocol 2009-0468. Kentucky Department of Fish and Wildlife Education Collecting Permit (#SC0911078) was obtained before live trapping begun.

Relative abundance of all small mammals and taxonomic richness were used to assess relative wildlife habitat quality of the switchgrass, corn, and hay habitats (further referred to as switchgrass, corn, and hay). Capture per unit effort (CPUE) indexes per 100 trapnights (one trap opened for one night equaled one trapnight) were calculated (total captures divided by total trapnights multiplied by 100) as the measure of relative abundance of small mammals (Elliott & Root 2006, Hopkins & Kennedy 2004, Pinkert et al. 2002, Stallman & Best 1996, Getz & Brighty 1986, Fleharty & Navo 1983). Taxonomic richness was calculated for each farm as opposed to species richness, because meadow voles and prairie voles were analyzed as *Microtus* spp. due to inconsistencies in field identification (Elliott & Root 2006).

Botanical species composition (%), maximum height of each species (cm), and vegetative density were recorded at 6 randomly selected areas using a 0.37 m^2 quadrat constructed of polyvinyl chloride (PVC) tubing within each trapping grid. Botanical species composition (species, debris, and bare soil) was visually estimated to the nearest five percent for each 0.37 m^2 area. A three meter Robel pole marked every five centimeters was used to record the maximum height of each species and vegetative density. Vegetative density was estimated as the average of four visual obstruction readings (VOR), the minimum five centimeter increment visible from a four meter distance and a one meter height, taken for each of the four cardinal directions (Robel et al. 1970). Weighted average heights were calculated using the species composition and maximum species height data.

Data Analysis

My study was analyzed as a randomized complete block design (RCBD) with farm as the blocking factor, farm and habitat within farm as the randomized treatment, and habitat within farm as the repeated measure using PROC MIXED in SAS 9.1 (SAS Institute Inc., Cary, NC, USA, 2003). Repeated measures analysis of variance (ANOVA) was used to determine significant effects of habitat, trapping session, and two-way interaction of these factors for relative abundance of all small mammals (CPUE), relative abundance by taxa (CPUE), taxonomic richness, and Robel pole and weighted average height measurements. In addition, similar repeated measures ANOVA was used to test for corn tillage system and switchgrass stand age significant effects which were analyzed as completely randomized designs (CRD) with farm as the randomized treatment and trap as the experimental unit using PROC MIXED in SAS 9.1 (SAS Institute Inc., Cary, NC, USA, 2003). Means separations were performed for significant effects on least square means using the PDIFF option.

The relationship between relative abundance of all small mammals (CPUE) and Robel pole and weighted average height measurements were analyzed using linear regression and Pearson's correlation tests using PROC REG and PROC CORR in SAS 9.1 (SAS Institute Inc., Cary, NC, USA, 2003). All tests were considered significant at $P \leq 0.05$.

CHAPTER IV: Results

Relative Abundance of Small Mammals

A total of 497 captures of six species of small mammals, white-footed mice, prairie deer mice (further referred to as deer mice), house mice, meadow voles, prairie voles, and northern short-tailed shrews, were made during 4,605 trapnights (trapnights varied depending on session, farm, and habitat due to adverse weather conditions) with 287 captures in switchgrass (1,583 trapnights), 160 in corn (1,548 trapnights), and 50 in hay (1,474 trapnights) (Table 4.1). Meadow voles and prairie voles were analyzed as *Microtus* spp. due to inconsistencies in field identification (Elliott & Root 2006); as a result, five small mammal taxa were used for data analysis.

A significant interaction was observed between habitat and trapping session for relative abundance of small mammals ($F_{6,26} = 3.24$, $P = 0.0162$). This effect was attributed to dissimilar temporal changes in relative abundance of small mammals between trapping sessions in the three habitats. Relative abundance of small mammals in switchgrass and corn varied between trapping sessions, but remained low in hay throughout the study (Figure 4.1). In switchgrass, relative abundance of small mammals had an increasing trend from spring through fall and then decreased in the winter after the late-fall harvest. In corn, relative abundance of small mammals increased from spring to summer, but then had a decreasing trend through winter after the onset of senescence. Consequently, switchgrass and corn had a greater relative abundance of small mammals than hay in the summer, and switchgrass had a greater relative abundance of small mammals then corn and hay in the fall. There were no significant differences between habitats in the spring and winter (Figure 4.1). The relative abundance of small mammals was greatest in switchgrass and corn during the summer and switchgrass during the fall; all other relative abundances were not significantly different than the lowest relative abundance recorded (Figure 4.1).

A significant interaction was observed between habitat and trapping session for relative abundance of small mammals between the corn tillage systems, NT and CT ($F_{3,566} = 8.75$, $P = <0.0001$). Relative abundance of small mammals was greater in NT corn in the summer, fall, and winter, but not significantly different than CT in the spring

(Figure 4.2). Both corn tillage systems exhibited similar temporal trends, as previously described, with an initial increase in relative abundance from spring to summer and then a decreasing trend over time (Figure 4.2).

A significant interaction was observed between habitat and trapping session for relative abundance of small mammals between switchgrass stand ages, two and three year old stands ($F_{3,566} = 14.29$, $P = <0.0001$). Relative abundance of small mammals was greater in three year old stands in the spring, summer, and winter, but not significantly different than two year old stands in the fall (Figure 4.3). Relative abundance in the two and three year old switchgrass stands exhibited dissimilar temporal changes. The two year old switchgrass stands had a similar temporal trend, as previously mentioned, with an increasing trend from spring through fall and a decrease in the winter. Relative abundance in three year old switchgrass stands increased from spring to summer and remained at this increased abundance for the remainder of the study.

Table 4.1 Summary of trapnights, captures by taxa, and relative abundance of small mammals (CPUE; per 100 trapnights).

Trapping Session	Habitat	Farm	Trapnights	*P. leucopus*	*P. maniculatus*	*M. musculus*	*Microtus* spp.	*B. brevicauda*	Total	CPUE	Average CPUE
Spring	Corn	Boyd_S	72	1	0	0	0	0	1	1.39	
		Fayette	108	0	7	1	0	0	8	7.41	
		Lewis	108	0	1	0	0	0	1	0.93	
		Boyd_N	72	1	0	0	0	0	1	1.39	2.78
	Hay	Boyd_S	106	0	0	2	0	0	2	1.89	
		Fayette	0	-	-	-	-	-	-	-	
		Lewis	108	0	1	0	0	0	1	0.93	
		Boyd_N	72	3	0	1	0	0	4	5.56	2.79
	Switchgrass	Boyd_S	107	0	0	0	0	0	0	0.00	
		Fayette	108	13	3	0	0	0	16	14.81	
		Lewis	108	2	2	0	0	0	4	3.70	
		Boyd_N	72	1	0	0	0	0	1	1.39	4.98
Summer	Corn	Boyd_S	108	2	0	4	0	0	6	5.56	
		Fayette	108	1	29	8	0	0	38	35.19	
		Lewis	108	6	5	7	0	0	18	16.67	
		Boyd_N	108	34	0	1	0	0	35	32.41	22.45
	Hay	Fayette	108	0	0	0	1	0	1	0.93	
		Boyd_S	108	0	0	0	0	0	0	0.00	
		Lewis	108	1	1	0	8	0	10	9.26	
		Boyd_N	108	0	0	0	0	0	0	0.00	2.55
	Switchgrass	Boyd_S	108	0	0	2	2	0	4	3.70	
		Fayette	108	48	4	0	0	1	53	49.07	
		Lewis	108	8	0	0	0	0	8	7.41	
		Boyd_N	108	0	0	1	13	1	15	13.89	18.52

Table 4.1 (continued) Summary of trapnights, captures by taxa, and relative abundance of small mammals (CPUE; per 100 trapnights).

Trapping Session	Habitat	Farm	Trapnights	*P. leucopus*	*P. maniculatus*	*M. musculus*	*Microtus* spp.	*B. brevicauda*	Total	CPUE	Average CPUE
Fall	Corn	Boyd_S	108	0	0	0	0	0	0	0.00	
		Fayette	108	9	12	0	0	0	21	19.44	
		Lewis	108	7	2	2	0	0	11	10.19	
		Boyd_N	72	8	0	1	0	0	9	12.50	10.53
	Hay	Boyd_S	108	0	0	0	0	0	0	0.00	
		Fayette	108	0	0	0	0	0	0	0.00	
		Lewis	108	0	0	0	14	1	15	13.89	
		Boyd_N	72	0	0	0	0	0	0	0.00	3.47
	Switchgrass	Boyd_S	108	0	0	22	14	0	36	33.33	
		Fayette	108	32	0	0	7	1	40	37.04	
		Lewis	108	6	0	2	10	0	18	16.67	
		Boyd_N	72	0	0	5	20	0	25	34.72	30.44
Winter	Corn	Boyd_S	72	0	0	0	0	0	0	0.00	
		Fayette	108	2	8	0	0	0	10	9.26	
		Lewis	108	0	0	0	0	0	0	0.00	
		Boyd_N	72	1	0	0	0	0	1	1.39	2.66
	Hay	Boyd_S	72	0	0	0	1	0	1	1.39	
		Fayette	108	0	16	0	0	0	16	14.81	
		Lewis	108	0	0	0	0	0	0	0.00	
		Boyd_N	72	0	0	0	0	0	0	0.00	4.05
	Switchgrass	Boyd_S	72	1	0	0	0	0	1	1.39	
		Fayette	108	36	13	3	0	0	52	48.15	
		Lewis	108	3	9	0	0	2	14	12.96	
		Boyd_N	72	0	0	0	0	0	0	0.00	15.63
Total	Corn		1548	72	64	24	0	0	160		
Total	Hay		1474	4	18	3	24	1	50		
Total	Switchgrass		1583	150	31	35	66	5	287		
Grand Total			4605	226	113	62	90	6	497		

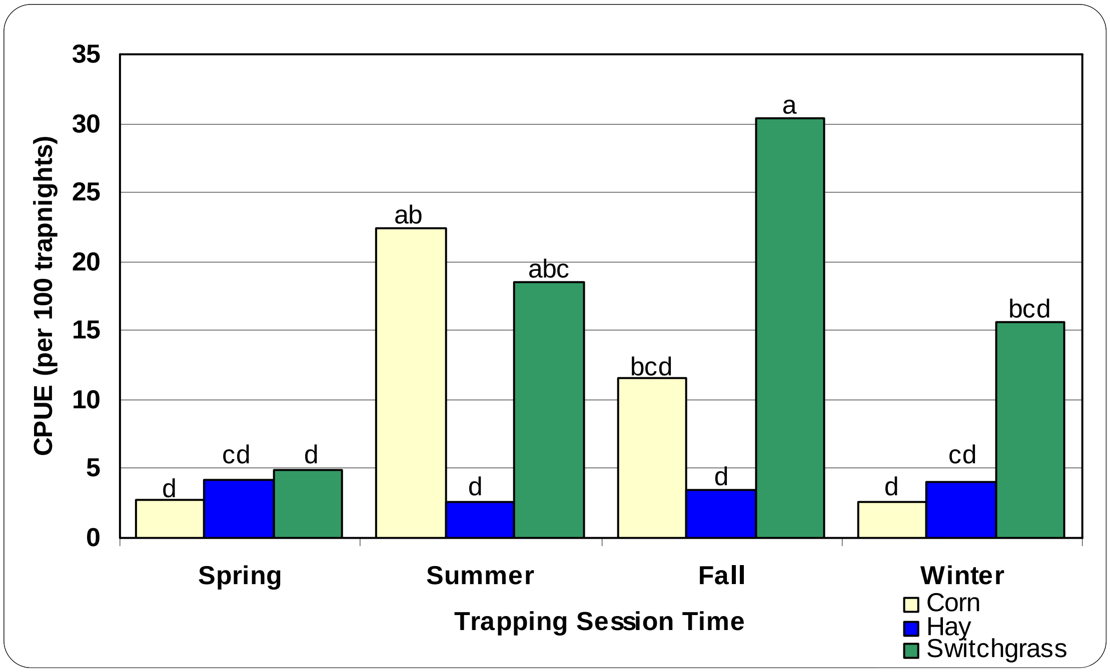

Figure 4.1 Relative abundance of small mammals (CPUE) comparison for corn, hay, and switchgrass. Least square means with the same letter are not significantly different ($P \leq 0.05$).

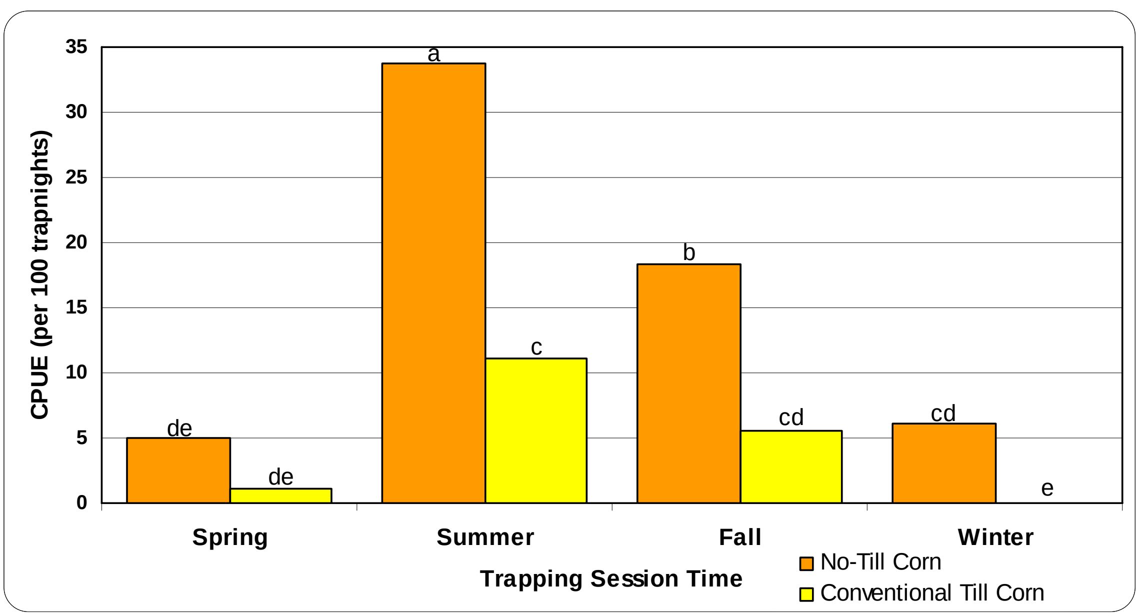

Figure 4.2 Relative abundance of small mammals (CPUE) comparison for corn tillage system. Least square means with the same letter are not significantly different ($P \leq 0.05$).

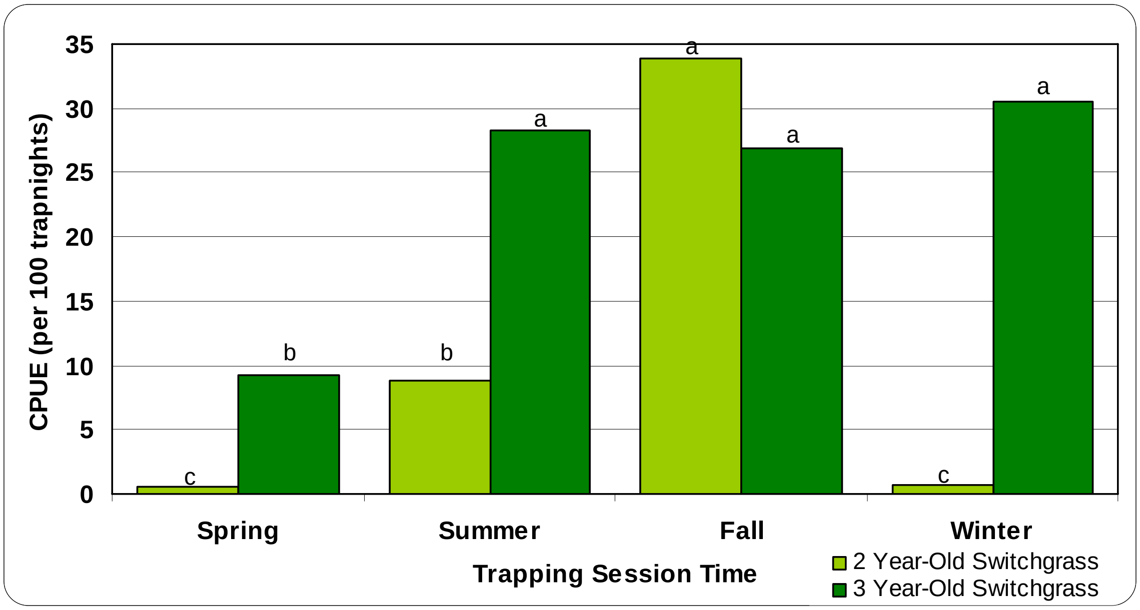

Figure 4.3 Relative abundance of small mammals (CPUE) comparison for switchgrass stand age. Least square means with the same letter are not significantly different ($P \leq 0.05$).

Relative Abundance by Taxa

Of the five small mammal taxa analyzed only house mice and *Microtus* spp. showed significant differences for relative abundance across land use and trapping sessions (Tables 4.2, 4.3). There was a significant interaction between habitat and trapping session for relative abundance of house mice and *Microtus* spp. ($F_{6,26} = 2.95$, $P = 0.0250$; $F_{6,26} = 4.53$, $P = 0.0029$, respectively). The greatest relative abundance of house mice was corn in the summer and switchgrass in the fall (Table 4.2). All other relative abundances were not significantly different than the lowest relative abundance recorded. Relative abundance of *Microtus* spp. was greater in switchgrass during the fall than all other relative abundances recorded (Table 4.3).

Table 4.2 Relative abundance of house mice (CPUE; per 100 trapnights) comparison for corn, hay, and switchgrass.

	Spring	Summer	Fall	Winter
Corn	0.23c*	4.63ab	0.81bc	0.00c
Hay	1.01bc	0.00c	0.00c	0.00c
Switchgrass	0.00c	0.69bc	7.29a	0.69bc

*Least square means with the same letter are not significantly different ($P \leq 0.05$).

Table 4.3 Relative abundance of *Microtus* spp. (CPUE; per 100 trapnights) comparison for corn, hay, and switchgrass.

	Spring	Summer	Fall	Winter
Corn	0.00b*	0.00b	0.00b	0.00b
Hay	0.00b	2.08b	3.24b	0.35b
Switchgrass	0.00b	3.47b	14.12a	0.00b

*Least square means with the same letter are not significantly different ($P \leq 0.05$).

Taxonomic Richness of Small Mammals

Over the duration of this study, all five small mammal taxa were captured in switchgrass and hay, while only the white-footed mouse, deer mouse, and house mouse were captured in corn (Table 4.4). The mean taxonomic richness was calculated and used to determine significant effects since taxonomic richness varied between farms (Tables 4.4 and 4.5). A significant habitat effect was observed for mean taxonomic richness at a significance of $P \leq 0.10$ ($F_{2,6} = 3.86$, $P = 0.0837$). Switchgrass had a greater mean taxonomic richness than hay and corn was an intermediate (Table 4.5).

Taxonomic richness was not statistically analyzed to determine significant effects for corn tillage system and switchgrass stand age due to low site replication. Even so, it is unlikely there would have been significant effects. Over the four corn plots, white-footed mouse, deer mouse, and house mouse were the only species captured and were found in both NT and CT plots. Over the four switchgrass plots, four of the five small mammal taxa were captured in both the two and three year old switchgrass stands. Deer mice were not captured in two year old switchgrass; however, this was a result of both two year old switchgrass stands being located in Boyd County which is outside the geographical range for deer mice.

Table 4.4 Taxonomic richness of small mammals for corn, hay, and switchgrass with "X" symbolizing the presence of the species.

Farm	Habitat	*P. leucopus*	*P. maniculatus*	*M. musculus*	*Microtus* spp.	*B. brevicauda*	Taxonomic Richness
Boyd_S	Corn (CT)	X		X			2
	Hay			X			1
	Switchgrass (2 yrs old)			X	X		2
Fayette	Corn (NT)	X	X	X			3
	Hay				X		1
	Switchgrass (3 yrs old)	X	X		X	X	4
Lewis	Corn (CT)	X	X	X			3
	Hay	X	X		X	X	4
	Switchgrass (3 yrs old)	X	X	X	X		4
Boyd_N	Corn (NT)	X		X			2
	Hay	X		X			2
	Switchgrass (2 yrs old)	X		X	X	X	4
Total	Corn	X	X	X			3
Total	Hay	X	X	X	X	X	5
Total	Switchgrass	X	X	X	X	X	5

Table 4.5 Mean taxonomic richness comparison for corn, hay, and switchgrass.

	Mean Taxonomic Richness
Corn	2.75ab*
Hay	2.00b
Switchgrass	3.50a

*Least square means with the same letter are not significantly different ($P \leq 0.05$).

Vegetative Characteristics

A significant interaction was observed between habitat by trapping session for Robel pole and weighted average height measurements ($F_{4,15} = 3.08$, $P = 0.0491$; $F_{6,21} = 22.46$, $P = \leq 0.0001$, respectively). The habitat and trapping sessions with the greatest Robel pole measurements were switchgrass and corn in the summer and fall (Table 4.6). All other habitat and trapping session Robel pole measurements were not significantly different than the lowest value. The habitat and trapping sessions with the greatest weighted average heights were switchgrass in the summer and fall, followed by hay in the spring and corn in the summer, and then corn in the fall (Table 4.6). All other habitat and trapping session weighted average heights were not significantly different than the lowest value.

Table 4.6 Summary of Robel pole and weighted average height measurements for corn, hay, and switchgrass.

Trapping Session	Habitat	Robel Pole (cm)	Weighted Average Height (cm)
Spring	Corn	-	0.45d
	Hay	-	77.71b
	Switchgrass	-	27.04cd
Summer	Corn	126.05A*	59.54b
	Hay	20.85BC	22.61cd
	Switchgrass	129.89A	108.78a
Fall	Corn	71.72AB	34.09c
	Hay	14.06BC	17.68cd
	Switchgrass	113.64A	113.47a
Winter	Corn	7.66C	4.33d
	Hay	7.71C	11.62cd
	Switchgrass	7.55C	5.01d
Average	Corn	68.48	24.60
Average	Hay	14.21	32.41
Average	Switchgrass	83.69	63.58

*Least square means with the same letter within the same column are not significantly different ($P \leq 0.05$).

Linear Regression and Correlation Analysis

Relative abundance of small mammals was significantly correlated with Robel pole and weighted average height measurements ($F_{1,31} = 11.76$, $P = 0.0017$, $R^2 = 0.275$, $Y = 0.1143X + 4.9943$; $F_{1,40} = 9.43$, $P = 0.0038$, $R^2 = 0.1907$, $Y = 0.1278X + 4.0144$, respectively). However, the relative abundance of small mammals in switchgrass during the winter at the Fayette farm was a significant outlier for both Robel pole and weighted average height correlations and consequently removed from the analyses (student residual = 3.807; 3.966, respectively). As a result, both correlations remained significant and had an increased coefficient of determination (R^2) ($F_{1,30} = 27.47$, $P = \leq 0.0001$, $R^2 = 0.478$, $Y = 0.1307X + 2.8077$; $F_{1,39} = 19.92$, $P = \leq 0.0001$, $R^2 = 0.3381$, $Y = 0.1477X + 2.1755$, respectively) (Figure 4.4 and 4.5). The Robel pole and relative abundance of small mammals correlation had a stronger relationship than the weighted average height correlation with a greater R^2 value ($R^2 = 0.478$; $R^2 = 0.3381$, respectively).

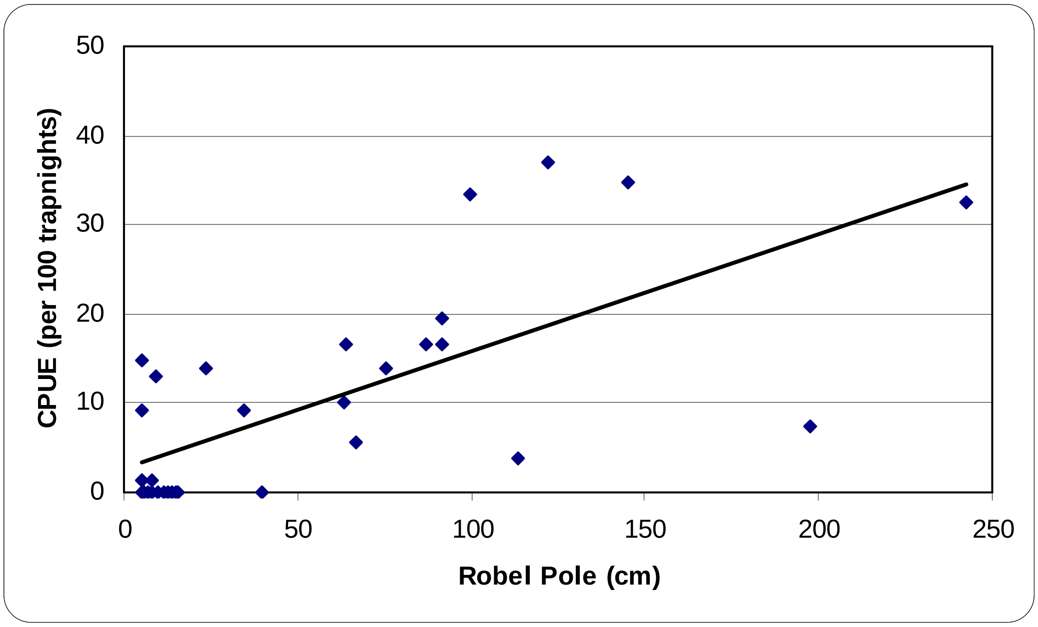

Figure 4.4 Linear regression and Pearson's correlation between relative abundance of small mammals (CPUE) and Robel pole measurements with the outlier, Fayette farm switchgrass in winter, removed ($F_{1,30}$ = 27.47, P = ≤0.0001, R^2 = 0.478, Y = 0.1307X + 2.8077, outlier student residual = 3.807).

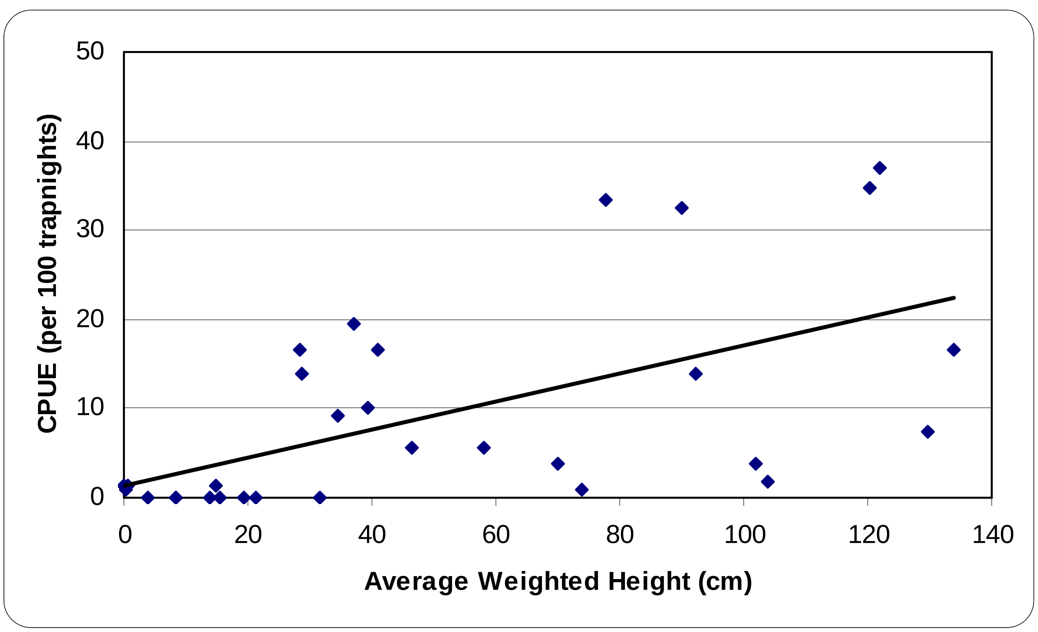

Figure 4.5 Linear regression and Pearson's correlation between relative abundance of small mammals (CPUE) and weighted average height measurements with one outlier, Fayette farm switchgrass in winter, removed ($F_{1,39}$ = 19.92, P = ≤0.0001, R^2 = 0.3381, Y = 0.1477X + 2.1755, outlier student residual = 3.966).

CHAPTER V: Discussion

This study is one of the first to compare small mammal populations in switchgrass stands managed for biomass production compared to other common land uses, specifically hay and corn fields. Most small mammal species experience an annual population cycle with a relatively low population density in the spring, an increasing density through the fall, and then a steady decline through the winter caused by a decrease in reproduction (Taitt & Krebs 1983, Stickel 1979). Results showed that the annual population abundance trend, the magnitude of abundance, and taxonomic richness of small mammal populations in switchgrass, corn, and hay were influenced by habitat characteristic changes and disturbance throughout the year.

Vegetative cover, including the standing crop and litter, is known to be an important characteristic in habitat quality for small mammals (Peles & Barrett 1996), because it provides food (Taitt & Krebs 1983), protection from predators (Hines 1995, Taitt & Krebs 1983), and material to construct nests and runways (Peles & Barrett 1996). The positive relationship between vegetative cover and relative abundance of small mammals in this study reflects this importance and is consistent with previous studies (Els & Kerley 1996, Germano & Lawhead 1986). The reduction of vegetative cover as a result of harvest seemed to be the primary cause of the decreased relative abundance of small mammals in switchgrass and the consistently low relative abundance in hay. Relative abundance in switchgrass steadily increased until the late-fall harvest and then decreased to relative abundance levels similar to spring and summer. Relative abundance of small mammals was consistently low in hay throughout the study, which corresponds with the frequent reduction in vegetative cover as a result of the three hay harvests.

The decreased small mammal abundance in switchgrass and hay in this study is consistent with previous studies. Washburn & Seamans (2007) and Barras & Carrara (2000) reported decreased small mammal abundance in harvested hay fields, and Kaufman & Kaufman (2008), Kaufman et al. (2000), and Sietman et al. (1994) reported decreased small mammal abundance in harvested tallgrass prairies. No known studies exist on how harvesting switchgrass influences small mammal populations, but studies on the relationship of harvesting tallgrass prairies and small mammal populations do exist (Kaufman & Kaufman 2008, Kaufman et al. 2000, Sietman et al. 1994, Lemen & Clausen

1984). LoBue & Darnell (1959) (hay fields) and Lemen & Clausen (1984) (tallgrass prairie) reported a genre-specific response to grassland harvest with genre that prefer sufficient vegetative cover (e.g. *Microtus*) decreasing in abundance and species that prefer sparse cover (e.g. *Peromyscus* (Gloger)) increasing in abundance. In hay, results of this study showed greater captures of deer mice and less captures of *Microtus* spp. after harvest, but the changes were not significant. In switchgrass, results showed a significant decrease in relative abundance of *Microtus* spp. after harvest and greater captures of white-footed mice and deer mice, but the increases in mice abundance were not significant.

Harvest frequency also influences the negative harvest effects on small mammal abundance (Hall & Willig 1994). Frequently harvested fields have a greater reduction in small mammal abundance (Hall & Willig 1994), while infrequently harvested fields allow populations to recover to pre-harvest abundance levels (LoBue & Darnell 1959). The consistently low relative abundance in hay fields throughout this study may have resulted from a high harvest frequency, which prevented the necessary vegetative regrowth to promote small mammal population recovery.

Although vegetative cover may explain the relative abundance of small mammal trend in switchgrass, the relative abundance trend was not consistent between the two and three year old switchgrass stands. Switchgrass stands typically do not reach maximum above-ground production until the third growing season, because plant growth during the first two seasons is primarily in the root system (Parrish & Fike 2005). As a result of the more-developed root system, the three year old switchgrass stands were able to produce greater above-ground growth earlier in the year, which resulted in the greater relative abundance of small mammals during the spring and summer. Relative abundance of small mammals in the two year old switchgrass stands reached similar abundances in the fall. Seeds, an important food source in many small mammal diets due to seasonal abundance, high calorie and nutrient content, resistance to spoilage, and ease of transport and caching (Tannenbaum et al. 1998), were available in the fall and may have also positively influenced the relative abundance of small mammals in the two and three year old switchgrass stands. Kaufman et al. (2000) claimed the habitat in their study with the greatest reported abundance of small mammals was due to high production of weed and grain seeds. After harvest, the three year old switchgrass stands again had a greater relative abundance even though vegetative cover was similar.

Relative abundance of small mammals in corn was also correlated with vegetative cover, but harvest was not the only factor that decreased vegetative cover. Relative abundance and vegetative cover increased from spring to summer, but began a decreasing trend throughout the remainder of the study. The reduced vegetative cover from summer to fall may have resulted from senescence of corn leaves that previously provided cover between corn rows and stalks. Harvest likely resulted in the continued decrease in vegetative cover and relative abundance of small mammals from fall to winter.

Harvest effects on small mammal populations in corn are not well documented (Pinkert et al. 2002), but research has shown that mice, reported as the primary residents of corn (Pinkert et al. 2002, Albers et al. 1990, Clark & Young 1986, Getz & Brighty 1986, Warburton & Klimstra 1984, Stickel 1979), are negatively affected by harvest (Pinkert et al. 2002, Williams et al. 1994, Stickel 1979). Pinkert et al. (2002) and Williams et al. (1994) reported prairie deer mice and house mice populations ultimately decreasing after corn harvest, although Williams et al. (1994) found an initial increase in house mice abundance due to remnant waste grain. No known studies exist on how corn senescence effects small mammal populations.

Although the relative abundance of small mammal trend was consistent between no-till corn and conventionally tilled corn, relative abundance differed with no-till corn having a greater relative abundance than conventionally tilled corn during the summer, fall, and winter. Warburton & Klimstra (1984) also reported greater small mammal abundance in no-till corn compared to conventionally tilled corn. Warburton & Klimstra (1984) claimed the greater abundance resulted from the increased vegetation and debris in no-till corn, as well as the larger invertebrate population that the small mammals used as an important food source (Clark & Young 1986, Warburton & Klimstra 1984, Whitaker 1966). Sterner et al. (2003) and Johnson (1986) claim the lack of tillage also positively influences small mammal populations by allowing the establishment of burrow systems. The presence of established burrow systems in this study may have positively influenced the greater relative abundance of small mammals in no-till corn; however, no known studies have documented this relationship. Cromar et al. (1999) stated the greater amount of debris and lack of disturbance caused by tillage results in a more stable environment for small mammal populations. In this study, the greater amount of debris, vegetation, and presence of burrow systems were noticeable in no-till corn; however, the direct use of burrow systems was only witnessed during the winter trapping session (Schwer personal observation).

Although significant, the low coefficient of determination of the two correlations between relative abundance and vegetative measurements (Robel pole and weighted average height) may be indications that other factors influenced relative abundance of small mammals. The low coefficient of determinations may reflect the low relative abundance of small mammals in hay during the spring when vegetative cover was abundant and the high relative abundance of small mammals in the three year old switchgrass stands after harvest. The low relative abundance in hay during the spring may be a result of the population being at a typical seasonal low (Taitt & Krebs 1983, Stickel 1979). The factors resulting in the relatively high abundance in the three year old switchgrass are currently unknown.

Even though both correlations were significant, I recommend the use of the Robel pole method, or similar visual obstruction measurement, over the weighted average height method to estimate vegetative structure and potential wildlife habitat quality for small mammals. Robel pole was superior to weighted average height due to the stronger correlation with relative abundance, less subjectivity, and ease of recording and computing data.

Microtus spp. and house mice were the only species that exhibited significant differences in relative abundance between switchgrass, corn, and hay. *Microtus* spp. had a greater relative abundance in switchgrass during the fall than any other time in switchgrass, corn, and hay. High vegetative cover and available seed during the fall in switchgrass may have resulted in the greater relative abundance. House mice showed a preference for switchgrass and corn, but at different times of year. They had high relative abundance in corn during the spring and high relative abundance in switchgrass during the fall. Stickel (1979) reported migration as the primary factor driving house mice populations from unsuitable to suitable habitats in agricultural systems. If migration was also the driving factor in this study, house mice may have migrated from the corn to switchgrass due to the close proximity; however, the migration patterns of the small mammals are not known.

Small mammal taxonomic richness also differed between switchgrass, corn, and hay habitats. Mean taxonomic richness of the three habitats in descending order was switchgrass, corn, and hay of which switchgrass was significantly greater than hay but not corn. The high harvest frequency of hay likely also resulted in the low mean taxonomic richness. Washburn & Seamans (2007) and Barras & Carrara (2000) reported decreased species richness as a result of hay harvest. Hall & Willig (1994) reported decreased species richness in frequently harvested hay fields compared to no reductions in species richness in infrequently harvested hay fields. Even though four genera of small mammals were captured in switchgrass (*Microtus*, *Peromyscus*, *Mus*, and *Blarina*) and only two captured in corn (*Peromyscus* and *Mus*), mean taxonomic richness was not significantly different between these two habitats.

CHAPTER VI: Conclusion

The results of this research suggest that vegetative cover, which was affected by harvest, stand age, and tillage system, influenced seasonal abundance trends, overall abundance, and taxonomic richness of small mammal populations in agricultural systems of Kentucky. Switchgrass, especially three year old stands, provided habitat capable of supporting a greater richness of small mammals than hay, and sustained a greater relative abundance of small mammals than hay during the summer and corn and hay during the fall.

This study provided information on the potential wildlife habitat quality of switchgrass stands managed as a renewable energy crop compared to hay and corn fields, which will aid in better understanding the potential wildlife habitat quality changes on a regional scale if switchgrass becomes a viable agricultural commodity in the future. According to the results, switchgrass stands managed as a renewable energy crop have the potential to be viable wildlife habitat for small mammal species, other wildlife species with similar habitat requirements, and wildlife species that utilize small mammals as a primary food source.

CHAPTER VII: Future Directions

A mark-recapture study conducted over multiple sites and years is warranted to better understand the driving mechanisms influencing relative abundance and diversity of small mammals in switchgrass stands managed for biomass production. A multiple year study of a pre-established stand through maturity would also allow further understanding of the temporal delay in habitat quality shown by the greater relative abundance of small mammals in the three year old switchgrass stands compared to the two year old stands. Mark-recapture studies are often conducted because they provide more detailed population data, like population size, resident population size, migration patterns, birth rates, and death rates, that would help determine the driving mechanisms and temporal fluctuations.

Research investigating alternative switchgrass management practices, like establishing botanically diverse stands, seeding at a lower planting density, and practicing partial and/or spring harvests, is also warranted to potentially increase the wildlife habitat stand quality. Botanically diverse stands that include additional native, warm-season grasses, like big bluestem (*Andropogon gerardiii* (Vitman)), little bluestem (*Schizachyrium scoparium* (Michx.) Nash)), and indiangrass (*Sorghastrum nutans* ((L.) Nash)), would have a greater vegetative heterogeneity compared to switchgrass monocultures. Since vegetative structure complexity is positively correlated with abundance and diversity of small mammals (Olson & Brewer 2003, Peles & Barrett 1996, Germano & Lawhead 1986, Johnson 1986, Pizzimenti & De Salle 1981), the increased heterogeneity may result in a greater abundance and diversity of small mammals. In addition, highly diverse stands have been shown to yield larger biomass production than switchgrass monocultures (Tilman et al. 2006).

This study investigated switchgrass stands planted at 11.2 kilograms PLS per hectare, which may be a planting density that hinders movement and stand use by wildlife. The USDA-NRCS states that a stand density of three to six plants per 0.18 square meters during the establishment year and one to two plants per 0.18 square meters during the second growing season is sufficient for a successful switchgrass stand (United States 2009). Research investigating the wildlife habitat quality of stands planted at multiple planting densities is warranted.

Late-winter and strip harvests are alternative harvest methods that may result in a smaller disturbance on small mammal populations compared to a late-fall harvest. Late-winter harvests provide protective cover almost year-round, but yields will be lower than late-fall harvests. Slade & Crain (2006) studied the effects of strip-harvesting hay fields (15 meter wide strips) on small mammal populations and reported a quick recovery by small mammal communities post-disturbance. Fargione et al. (2009) suggested that the best harvest scenario to maximize wildlife habitat quality is one that creates a mosaic of harvested and unharvested patches to provide cover throughout the year; however, the optimum size of these patches is not yet known. As a result, a harvest strategy that combines late-winter and strip-harvesting may result in the best case scenario since it provides winter cover and reduces yield loss. Strip-harvesting may also benefit bird populations by creating tall and short vegetated areas to be used by a greater diversity of bird species (Murray et al. 2003b).

Diversifying the habitat mosaic of a farm by establishing a switchgrass stand could positively influence the overall habitat quality of the farm stead. A diverse cluster of vegetative communities could have a positive influence on abundance, diversity, and distribution of small mammals and other wildlife species on a larger scale (Clark et al. 1998, Els & Kerley 1996).

References

Albers, P.H., G. Linder, and J.D. Nichols. 1990. Effects of tillage practices and carbofuran exposure on small mammals. Journal of Wildlife Management 54:135-142.

Barbour, R.W. and W.H. Davis. 1974. Mammals of Kentucky. The University Press of Kentucky, Lexington, KY.

Barras, S.C. and M.S. Carrara. 2000. Bird and small mammal use of mowed and unmowed vegetation at John F. Kennedy International Airport, 1998 to 1999. Proceedings of the 19th Vertebrate Pest Conference. University of California, Davis, CA.

Barrett, G.W., C.S. Haviland, and D.H. Taylor. 1990. Perturbation effects on deer mouse populations in corn agroecosystems. Ohio Journal of Science 90:125-129.

Beasley, L.E. and G.E. McKibben. 1976. Mouse control in no-till corn. Illinois Agriculture Experiment Station, Dixon Springs Agriculture Center, Simpson, Illinois. DSAC 4:27-30.

Best, L.B., H. Campa III, K.E. Kemp, R.J. Robel, M.R. Ryan, J.A. Savidge, H.P. Weeks Jr., and S.R. Winterstein. 1997. Bird abundance and nesting in CRP fields and cropland in the Midwest: A regional approach. Wildlife Society Bulletin 25:864-877.

Bilenca, D.N. 2007. Agricultural intensification and small mammal assemblages in agroecosystems of the Rolling Pampas, central Argentina. Agriculture, Ecosystems and Environment 121:371-375.

Birney, E.C., W.E. Grant, and D.D. Baird. 1976. Importance of vegetative cover to cycles of *Microtus* populations. Ecology 57:1043-1051.

Blair, W.F. 1948. Population density, life span, and mortality rates of small mammals in the blue-grass meadow and blue-grass field associations of southern Michigan. The American Midland Naturalist 40:395-419.

Blanco-Canqui, H. 2010. Energy crops and their implications on soil and environment. Agronomy Journal 102:403-419.

Block, E.K., T. E. Lacher, Jr., L.W. Brewer, G.P. Cobb III, and R.J. Kendall. 1999. Populations responses of *Peromyscus* resident in Iowa cornfields treated with the organophosphorus pesticide COUNTER®. Ecotoxicology 8:189-200.

Caldwell, L.D. 1986. Predatory bird behavior and tillage operations. The Condor 88:93-94.

Campbell, J.E., D.B. Lobell, R.C. Genova, and C.B. Field. 2008. The global potential of bioenergy on abandoned agriculture lands. Environmental Science & Technology 42:5791-5794.

Castrale, J.S. 1985. Responses of wildlife to various tillage conditions. Transactions of the North American Wildlife and Natural Resources Conference 50:142-156.

Clark, B.K., B.S. Clark, T.R. Homerding, and W.E. Munsterman. 1998. Communities of small mammals in six grass-dominated habitats of southeastern Oklahoma. American Midland Naturalist 139:262-268.

Clark, B.K., D.W. Kaufman, G.A. Kaufman, and E.J. Finck. 1987. Use of tallgrass prairie by *Peromyscus leucopus*. Journal of Mammalogy 68:158-160.

Clark, W.R. and R.E. Young. 1986. Crop damage by small mammals in no-till cornfields. Journal of Soil and Water Conservation 41:338-341.

Corry, R.C. 2004. Characterizing fine-scale patterns of alternative agricultural landscapes with landscape pattern indices. Landscape Ecology 20:591-608.

Cromar, H.E., S.D. Murphy, and C.J. Swanton. 1999. Influence of tillage and crop residue on postdispersal predation of weed seeds. Weed Science 47:184-194.

Debolt, S., J.E. Campbell, R. Smith, M. Montross, and J. Stork. 2009. Life cycle assessment of native plants and marginal lands for bioenergy agriculture in Kentucky as a model for south-eastern USA. Global Change Biology Bioenergy 1:308-316.

Edge, W.D., J.O. Wolff, and R.L. Carey. 1995. Density-dependent responses of gray-tailed voles to mowing. Journal of Wildlife Management 59:245-251.

Elliott, A.G. and B.G. Root. 2006. Small mammal responses to silvicultural and precipitation-related disturbance in northeastern Missouri riparian forests. Wildlife Society Bulletin 34:485-501.

Els, L.M, and G.I.H. Kerley. 1996. Biotic and abiotic correlates of small mammal community structure in the Groendal Wilderness Area, Eastern Cape, South Africa. Koedoe 39:121-130.

Fargione, J.E., T.R. Cooper, D.J. Flaspohler, J. Hill, C. Lehman, T. McCoy, S. McLeod, E.J. Nelson, K.S. Oberhauser, and D. Tilman. 2009. Bioenergy and wildlife: Threats and opportunities for grassland conservation. BioScience 59:767-777.

Fargione, J., J. Hill, S. Polasky, and P. Hawthorne. 2008. Land clearing and the biofuel carbon debt. Science 319:1235-1238.

Farrand, D.T. and M.R. Ryan. 2005. Impact of the Conservation Reserve Program on wildlife conservation in the Midwest. Fish and Wildlife Benefits of Farm Bill Program Update 41-62.

Fike, J.H., D.J. Parrish, D.D. Wolf, J.A. Balasko, J.T. Green Jr., M. Rasnake, and J.H. Reynolds. 2006. Long-term yield potential of switchgrass-for-biofuel systems. Biomass and Bioenergy 30:198-206.

Fleharty, E.D. and K.W. Navo. 1983. Irrigated cornfields as habitat for small mammals in the sandsage prairie region of Western Kansas. Journal of Mammalogy 64:367-379.

Fletcher Jr., R.J., B.A. Robertson, J. Evans, P.J. Doran, J.R.R. Alavalapati, and D.W. Schemske. 2010. Biodiversity conservation in the era of biofuels: Risks and opportunities. Frontiers in Ecology and the Environment doi:10.1890/090091.

Germano, D.J. and D.N. Lawhead. 1986. Species diversity and habitat complexity: does vegetation organize vertebrate communities in the Great Basin? Great Basin Ecology 46:711–720.

Getz, L.L. and E. Brighty. 1986. Potential effects of small mammals in high-intensity agricultural systems in East-Central Illinois, U.S.A. Agriculture, Ecosystems and Environment 15:39-50.

Giuliano, W.M. and S.E. Daves. 2002. Avian response to warm-season grass use in pasture and hayfield management. Biological Conservation 106:1-9.

Grant, W.E. and E.C. Birney. 1979. Small mammal community structure in North American grasslands. Journal of Mammalogy 60:23-36.

Hall, D.L. and M.R. Willig. 1994. Mammalian species composition, diversity, and succession in Conservation Reserve Program grasslands. The Southwestern Naturalist 39:1-10.

Hines, R. 1995. Rodent damage control in no-till corn and soybean production. Proceedings of the Seventh Eastern Wildlife Damage Management Conference, University of Nebraska, Lincoln, NE.

Holm, K.E. 1984. Small mammal populations and rodent damage in Nebraska no-tillage crop fields. M.S. thesis, University of Nebraska, Lincoln.

Hopkins, H.L. and M.L. Kennedy. 2004. An assessment of indices of relative and absolute abundance for monitoring populations of small mammals. Wildlife Society Bulletin 32:1289-1296.

Humbert, J., J. Ghazoul, and T. Walter. 2009. Meadow harvesting techniques and their impacts on field fauna. Agriculture, Ecosystems and Environment 130:1-8.

Jacob, J. 2003. Short-term effects of farming practices on populations of common voles. Agriculture, Ecosystems and Environment 95:321-325.

Jensen, K., C.D. Clark, P. Ellis, B. English, J. Menard, M. Walsh, and D. Ugarte. 2007. Farmer willingness to grow switchgrass for energy production. Biomass and Bioenergy 31:773-781.

Johnson, R. 1986. Wildlife damage in conservation tillage agriculture: A new challenge. Proceedings of the Twelfth Vertebrate Pest Conference, University of California, Davis, CA.

Kaufman, D.W. and E. D. Fleharty. 1974. Habitat selection by nine species of rodents in north-central Kansas. The Southwestern Naturalist 18:443-452.

Kaufman, D.W., G.A. Kaufman, and B.K. Clark. 2000. Small mammals in native and anthropogenic habitats in the Lake Wilson area of north-central Kansas. The Southwestern Naturalist 45:45-60.

Kaufman, D.W. and G.A. Kaufman. 1990. House mice (*Mus musculus*) in natural and disturbed habitats in Kansas. American Society of Mammalogists 71:428-432.

Kaufman, G.A. and D.W. Kaufman. 2008. Effects of haying on small mammals in mixed grass prairie of central Kansas. Transactions of the Kansas Academy of Science 111:275-282.

Kirsch, E.M. 1997. Small mammal community compostition in cornfields, roadside ditches, and prairies in Eastern Nebraska. Natural Areas Journal 17:204-211.

Larkin, J.L., D.S. Maehr, J.J. Krupa, J.J. Cox, K. Alexy, D.E. Unger, and C. Barton. 2008. Small mammal response to vegetation and spoil conditions on a reclaimed surface mine in Eastern Kentucky. Southeastern Naturalist 7:401-412.

Leis, S.A., D.M. Leslie Jr., D.M. Engle, and J.S. Fehmi. 2008. Small mammals as indicators of short-term and long-term disturbance in mixed prairie. Environmental Monitoring and Assessment 137:75-84.

Lemen, C.A. and M.K. Clausen. 1984. The effects of mowing on the rodent community of a native tall grass prairie in eastern Nebraska. Prairie Naturalist 16:5-10.

LoBue, J. and R.M. Darnell. 1959. Effect of habitat disturbance on a small mammal population. Journal of Mammalogy 40:425-437.

Lord, R.D. 1983. Rodent control programs: Use of the inked tracking board method in Mexico. Paho Bulletin 17:259-268.

Mankin, P.C. and R.E. Warner. 1999. Responses of eastern cottontails to intensive row-crop farming. Journal of Mammalogy 80:940-949.

Marino, P.C., K.L. Gross, and D.A. Landis. 1997. Weed seed loss due to predation in Michigan maize fields. Agriculture, Ecosystems and Environment 66:189-196.

McCoy, T.D., M.R. Ryan, and L.W. Burger, Jr. 2001. Grassland bird conservation: CP1 vs. CP2 plantings in Conservation Reserve Program fields in Missouri. The American Midland Naturalist 145:1-17.

McLaughlin, S.B. and M.E. Walsh. 1998. Evaluating environmental consequences of producing herbaceous crops for bioenergy. Biomass and Bioenergy 14:317-324.

McMillan, B.R., D.W. Kaufman, and G.A. Kaufman. 1999. Rare species of small mammals in northeastern Kansas tallgrass prairie. Proceedings of the North American Prairie Conference 16:120-126.

Menalled, F.D., P.C. Marino, K.A. Renner, and D.A. Landis. 2000. Post-dispersal weed seed predation in Michigan crop fields as a function of agricultural landscape structure. Agriculture, Ecosystems and Environment 77:193-202.

Moulton, M.P., J.R. Choate, and S.J. Bissell. 1981. Small mammals on revegetated agricultural land in eastern Colorado. Prairie Naturalist 13:99–104.

Murray, L.D. and L.B. Best. 2003a. Short-term bird response to harvesting switchgrass for biomass in Iowa. Journal of Wildlife Management 67:611-621.

Murray, L.D., L.B. Best, T.J. Jacobsen, and M.L. Braster. 2003b. Potential effects on grassland birds of converting marginal cropland to switchgrass biomass production. Biomass and Bioenergy 25:167-175.

Nickel, A.M., B.J. Danielson, and K.A. Moloney. 2003. Wooded habitat edges as refugia from microtine herbivory in tallgrass prairies. Oikos 100:525-533.

Olson, R.A. and M.J. Brewer. 2003. Small mammals populations occurring in a diversified winter wheat cropping system. Agriculture, Ecosystems and Environment 95:311-319.

Paine, L.K., T.L. Peterson, D.J. Undersander, K.C. Rineer, G.A. Bartelt, S.A. Temple, D.W. Sample, and R.M. Klemme. 1996. Some ecological and socio-economic considerations for biomass energy crop production. Biomass and Bioenergy 10:231-242.

Papendick, R.L. and K.F. Elliott. 1985. Different cropping systems in the United States and potential benefits to wildlife. Technical Papers USDA Agricultural Research Service, Washington State University, Pullman, WA.

Parrish, D.J. and J.H. Fike. 2005. The biology and agronomy of switchgrass for biofuels. Critical Review in Plant Sciences 24: 423-459.

Payne, T. and W. Caire. 1999. Species diversity of small mammals in the tallgrass prairie preserve, Osage County, Oklahoma. Proceedings of the Oklahoma Academy of Science 79:51-59.

Peles, J.D. and G.W. Barrett. 1996. Effects of vegetative cover on the population dynamics of meadow voles. Journal of Mammalogy 77:857-869.

Pinkert, M.K., J.R. Meerbeek, G.D. Scholten, and J.A. Jenks. 2002. Impact of crop harvest on small mammal populations in Brookings County, South Dakota. Proceedings of the South Dakota Academy of Science 81:39-45.

Pizzimenti, J.J. and R. De Salle. 1981. Factors influencing the distributional abundance of two trophic guilds of Peruvian cricetid rodents. Biological Journal of the Linnean Society 15:339-354.

Reid, F.A. 2006. The Peterson Field Guide Series® A Field Guide to Mammals of North America North of Mexico. Fourth Edition. Houghton Mifflin Company, Boston, NY.

Robel, R.J., J.N. Briggs, A.D. Dayton, and L.C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

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

Schauber, E.M., W.D. Edge, and J.O. Wolff. 1997. Insecticide effects on small mammals: Influence of vegetation structure and diet. Ecological Applications 7:143-157.

Schramm, P. and B.J. Willcutts. 1983. Habitat selection of small mammals in burned and unburned tallgrass prairie. In: R. Brewer ed., Proceedings of the Eight North American Prairie Conference Western Michigan University, Kalamazoo, MI: 49-55.

Sietman, B,E., W.B. Fothergill, and E.J. Finck. 1994. Effects of haying and old-field succession on small mammals in tallgrass prairie. The American Midland Naturalist 131:1-8.

Slade, N.A. and S. Crain. 2006. Impact on rodents of mowing strips in old fields of eastern Kansas. Journal of Mammalogy 87:97-101.

Spencer, R.J., V.C. Cavanough, G.S. Baxter, and M.S. Kennedy. 2005. Adult free zones in small mammal populations: Response of Australian native rodents to reduced cover. Austral Ecology 30:876-884.

Stallman, H.R. and L.B. Best 1996. Small-mammal use of an experimental strip intercropping system in Northeastern Iowa. American Midland Naturalist 135:266-273.

Sterner, R.T., B.E Petersen, S.E. Gaddis, K.L. Tope, and D.J. Poss. 2003. Impacts of small mammals and birds on low-tillage, dryland crops. Crop Protection 22:595-602.

Stickel, L.F. 1979. Population ecology of house mice in unstable habitats. Journal of Animal Ecology 48:871-887.

Taitt, M.J. and C.J. Krebs. 1983. Predation, cover, and food manipulations during a spring decline of *Microtus townsendii*. Journal of Animal Ecology 52:837-848.

Tannenbaum, M.G., S.L. Seematter, and D.M. Zimmerman. 1998. Endophyte-infected and uninfected fescue seeds suppress white-footed mouse (*Peromyscus leucopus*) reproduction. The American Midland Naturalist 139:114-124.

Tilman, D., J. Hill, and C. Lehman. 2006. Carbon-negative biofuels from low-input high-diversity grassland biomass. Science 314:1598-1600.

Tolbert, V.R. and L.L. Wright. 1998. Environmental enhancement of U.S. biomass crop technologies: Research results to date. Biomass and Bioenergy 15:93-100.

United States Department of Agriculture. 2007. The Census of Agriculture; National Agricultural Statistics Service. On-line. http://www.agcensus.usda.gov/2007.

United States Department of Agriculture. 2000. Economic Research Service; The Economics of Food, Farming, Natural Resources, and Rural America. Publication SB968, Glossary. http://www.ers.usda.gov/publications/sb968/sb968f.pdf.

United States Department of Agriculture, Natural Resources Conservation Service. 2009. Planting and managing switchgrass as a biomass energy crop. Technical Note No.3. On-line. http://plant-materials.nrcs.usda.gov/pubs/NPMtechnotes/npmptn3-13079.pdf.

United States Energy Information Administration Independent Statistics and Analysis. 2010. Renewable Energy Trends in Consumption and Electricity Table 1.1 U.S. Energy Consumption by Energy Source, 2004-2008. http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/rentrends.html.

Warburton, D.B. and W.D. Klimstra. 1984. Wildlife use of no-till and conventionally tilled corn fields. Journal of Soil and Water Conservation 39:327-330.

Washburn, B.E. and T.W. Seamans. 2007. Wildlife responses to vegetation height management in cool-season grasslands. Rangeland Ecology Management 60:319-323.

Wegner, J. and G. Merriam. 1990. Use of spatial elements in a farmland mosaic by a woodland rodent. Biological Conservation 54:263-276.

Whitaker Jr., J.O. 1967. Habitat relationships of four species of mice in Vigo County, Indiana. Ecology 48:867-872.

Whitaker Jr., J.O. 1966. Food of *Mus musculus*, *Peromyscus maniculatus bairdi*, *Peromyscus leucopus* in Vigo County, Indiana. Journal of Mammalogy 47:473-486.

Williams, C.K., V.A. Witmer, M. Casey, and G.W. Barrett. 1994. Effects of strip-cropping on small mammal population dynamics in soybean agroecosystems. Ohio Journal of Science 94:94-98.

Wullschleger, S.D., E.B. Davis, M.E. Borsuk, C.A. Gunderson, and L.R. Lynd. 2010. Biomass production in switchgrass across the United States: Database description and determinants of yield. Agronomy Journal 102:1158-1168.

Young, R.E. 1984. Response of small mammals to no-till agriculture in southwestern Iowa. MS. Thesis. Iowa State University, Ames, IA.

Zou, J., J.T. Flinders, H.L. Black, and S.G. Whisenant. 1989. Influence of experimental habitat manipulations on a desert rodent population in southern Utah. Great Basin Naturalist 49:435-448.

Appendix

Table A.1 Small mammals captured in grasslands with switchgrass as a dominant grass and the state they were located.

Scientific Name	Common name	Location(s)	Reference(s)
Blarina brevicauda	northern short-tailed shrew	IL, SD	Pinkert et al. 2002, Schramm & Willcutts 1983
Blarina carolinensis	southern short-tailed shrew	OK	Grant & Birney 1979, Birney et al. 1976
Blarina hylophaga	Elliot's short-tailed shrew	KS, OK	Kaufman et al. 2000, McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1998, Sietman et al. 1994, Clark et al. 1987
Chaetodipus hispidus	hispid pocket mouse	KS, OK	McMillan et al. 1999, Sietman et al. 1994, Clark et al. 1987, Grant & Birney 1979, Birney et al. 1976
Cryptotis parva	least shrew	KS, OK	McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1998, Clark et al. 1987, Grant & Birney 1979, Birney et al. 1976
Geomys bursarius	plains pocket gopher	KS	Sietman et al. 1994
Microtus ochrogaster	prairie vole	IL, KS, SD, OK	Pinkert et al.2002, Kaufman et al.2000, McMillan et al. 1999, Payne & Caire 1999, Sietman et al. 1994, Clark et al. 1987, Schramm & Willcutts1983, Grant & Birney 979, Birney et al. 1976
Microtus pennsylvanicus	meadow vole	IL, SD	Pinkert et al. 2002, Schramm & Willcutts 1983
Microtus pinetorum	woodland vole	KS, OK	McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1987
Mus musculus	house mouse	IL, KS, OK	McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1998, Clark et al. 1987, Schramm & Willcutts 1983, Grant & Birney 1979, Birney et al. 1976
Neotoma floridana	eastern woodrat	KS, OK	McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1987
Oryzomys palustris	marsh rice rat	OK	Clark et al. 1998
Peromyscus leucopus	white-footed mouse	IL, KS, OK	Kaufman et al. 2000, McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1998, Clark et al. 1987, Schramm & Willcutts 1983, Grant & Birney 1979, Birney et al. 1976
Peromyscus maniculatus	deer mouse	IL, KS, SD, OK	Pinkert et al. 2002, Kaufman et al. 2000, McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1998, Sietman et al. 1994, Clark et al. 1987, Schramm & Willcutts 1983, Grant & Birney 1979, Birney et al. 1976
Reithrodontomys megalotis	western harvest mouse	IL, KS, OK	Kaufman et al. 2000, McMillan et al. 1999, Payne & Caire 1999, Sietman et al. 1994, Clark et al. 1987, Schramm & Willcutts 1983
Reithrodontomys fulvescens	fulvous harvest mouse	OK	Payne & Caire 1999, Clark et al. 1998, Grant & Birney 1979, Birney et al. 1976
Reithrodontomys humulis	eastern harvest mouse	OK	Payne & Caire 1999
Reithrodontomys montanus	plains harvest mouse	KS, OK	McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1987, Grant & Birney 1979, Birney et al. 1976
Sigmodon hispidus	hispid cotton rat	KS, OK	Kaufman et al. 2000, McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1998, Sietman et al. 1994, Clark et al. 1987, Grant & Birney 1979, Birney et al. 1976
Sorex cinereus	masked shrew	IL, SD	Pinkert et al. 2002, Schramm & Willcutts 1983
Spermophilus tridecemlineatus	thirteen-lined ground squirrel	KS, OK	McMillan et al. 1999, Clark et al. 1987, Birney et al. 1976
Synaptomys cooperi	southern bog lemming	KS	Kaufman et al. 2000, McMillan et al. 1999, Clark et al. 1987
Zapus hudsonius	meadow jumping mouse	IL, KS	McMillan et al. 1999, Clark et al. 1987, Schramm & Willcutts 1983

Table A.2 Small mammal species and species richness captured in grasslands with switchgrass as a dominant grass and the state they were located.

Reference(s)	Location-Site	Species Richness	Species
Birney et al. 1976	OK	11	*Blarina carolinensis, Chaetodipus hispidus, Cryptotis parva, Microtus ochrogaster, Mus musculus, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys fulvescens, Reithrodontomys montanus, Sigmodon hispidus, Spermophilus tridecemlineatus*
Clark et al. 1998	OK-upland prairie	6	*Blarina hylophaga, Cryptotis parva, Mus musculus, Peromyscus maniculatus, Reithrodontomys fulvescens, Sigmodon hispidus*
Clark et al. 1998	OK-lowland prairie	6	*Mus musculus, Oryzomys palustris, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys fulvescens, Sigmodon hispidus*
Grant & Birney 1979	OK	10	*Blarina carolinensis, Chaetodipus hispidus, Cryptotis parva, Microtus ochrogaster, Mus musculus, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys fulvescens, Reithrodontomys montanus, Sigmodon hispidus*
Kaufman et al. 2000	KS-PG	7	*Blarina hylophaga, Microtus ochrogaster, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Sigmodon hispidus, Synaptomys cooperi*
McMillan et al. 1999; Clark et al. 1987	KS-Konza prairie	15	*Blarina hylophaga, Chaetodipus hispidus, Cryptotis parva, Microtus ochrogaster, Microtus pinetorum, Mus musculus, Neotoma floridana, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Reithrodontomys montanus, Sigmodon hispidus, Spermophilus tridecemlineatus, Synaptomys cooperi, Zapus hudsonius*
Payne & Caire 1999	OK-prairie	13	*Blarina hylophaga, Cryptotis parva, Microtus ochrogaster, Microtus pinetorum, Mus musculus, Neotoma floridana, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Reithrodontomys fulvescens, Reithrodontomys humulis, Reithrodontomys montanus, Sigmodon hispidus*
Pinkert et al. 2002	SD	5	*Blarina brevicauda, Microtus ochrogaster, Microtus pennsylvanicus, Peromyscus maniculatus, Sorex cinereus*
Schramm & Willcutts 1983	IL	9	*Blarina brevicauda, Microtus ochrogaster, Microtus pennsylvanicus, Mus musculus, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Sorex cinereus, Zapus hudsonius*
Sietman et al. 1994	KS-native	6	*Blarina hylophaga, Geomys bursarius, Microtus ochrogaster, Peromyscus maniculatus, Reithrodontomys megalotis, Sigmodon hispidus*
Sietman et al. 1994	KS-hayfield	6	*Blarina hylophaga, Chaetodipus hispidus, Geomys bursarius, Microtus ochrogaster, Peromyscus maniculatus, Sigmodon hispidus*

Table A.3 Small mammals captured in tallgrass prairies and the state they were located.

Scientific Name	Common name	Location(s)	Reference(s)
Blarina brevicauda	northern short-tailed shrew	IL, MN, NE, SD	Pinkert et al. 2002, Kirsch 1997, Schramm & Willcutts 1983, Grant & Birney 1979
Blarina carolinensis	southern short-tailed shrew	OK	Grant & Birney 1979, Birney et al. 1976
Blarina hylophaga	Elliot's short-tailed shrew	KS, OK	Kaufman et al. 2008, Kaufman et al. 2000, McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1998, Sietman et al. 1994, Clark et al. 1987
Chaetodipus hispidus	hispid pocket mouse	CO, KS, OK	McMillan et al. 1999, Clark et al. 1998, Sietman et al. 1994, Clark et al. 1987, Moulton et al. 1981, Grant & Birney 1979, Birney et al. 1976, Kaufman & Fleharty 1974
Cryptotis parva	least shrew	KS, OK	Kaufman et al. 2008, McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1998, Clark et al. 1987, Grant & Birney 1979, Birney et al. 1976
Dipodomys ordii	Ord's kangaroo rat	CO	Moulton et al. 1981
Geomys bursarius	plains pocket gopher	KS	Sietman et al. 1994
Microtus ochrogaster	prairie vole	IL, KS, NE, SD, OK	Kaufman et al. 2008, Pinkert et al. 2002, Kaufman et al. 2000, McMillan et al. 1999, Payne & Caire 1999, Kirsch 1997, Sietman et al. 1994, Clark et al. 1987, Lemen & Clausen 1984, Schramm & Willcutts 1983, Grant & Birney 1979, Birney et al. 1976, Kaufman & Fleharty 1974
Microtus pennsylvanicus	meadow vole	IL, MN, NE, SD	Pinkert et al. 2002, Kirsch 1997, Lemen & Clausen 1984, Schramm & Willcutts 1983, Grant & Birney 1979
Microtus pinetorum	woodland vole	KS, OK	McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1987
Mus musculus	house mouse	IL, KS, MN, OK	McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1998, Clark et al. 1987, Schramm & Willcutts 1983, Grant & Birney 1979, Birney et al. 1976
Neotoma floridana	eastern woodrat	KS, OK	Kaufman et al. 2008, McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1987
Onychomys leucogaster	northern grasshopper mouse	CO, KS	Moulton et al. 1981, Kaufman & Fleharty 1974
Oryzomys palustris	marsh rice rat	OK	Clark et al. 1998
Perognathus flavescens	plains pocket mouse	CO	Moulton et al. 1981
Peromyscus leucopus	white-footed mouse	CO, IL, KS, MN, NE, OK	Kaufman et al. 2008, Kaufman et al. 2000, McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1998, Kirsch 1997, Clark et al. 1987, Schramm & Willcutts 1983, Moulton et al. 1981, Grant & Birney 1979, Birney et al. 1976, Kaufman & Fleharty 1974
Peromyscus maniculatus	deer mouse	CO, IL, KS, MN, NE, SD, OK	Kaufman et al. 2008, Pinkert et al. 2002, Kaufman et al. 2000, McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1998, Kirsch 1997, Sietman et al. 1994, Clark et al. 1987, Lemen & Clausen 1984, Schramm & Willcutts 1983, Moulton et al. 1981, Grant & Birney 1979, Birney et al. 1976, Kaufman & Fleharty 1974

Table A.3 (cont.) Small mammals captured in tallgrass prairies and the state they were located.

Scientific Name	**Common name**	**Location(s)**	**Reference(s)**
Reithrodontomys megalotis	western harvest mouse	CO, IL, KS, NE, OK	Kaufman et al. 2008, Kaufman et al. 2000, McMillan et al. 1999, Payne & Caire 1999, Kirsch 1997, Sietman et al. 1994, Clark et al. 1987, Lemen & Clausen 1984, Schramm & Willcutts 1983, Moulton et al. 1981, Kaufman & Fleharty 1974
Reithrodontomys fulvescens	fulvous harvest mouse	OK	Payne & Caire 1999, Clark et al. 1998, Grant & Birney 1979, Birney et al. 1976
Reithrodontomys humulis	eastern harvest mouse	OK	Payne & Caire 1999
Reithrodontomys montanus	plains harvest mouse	CO, KS, OK	McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1987, Moulton et al. 1981, Grant & Birney 1979, Birney et al. 1976, Kaufman & Fleharty 1974
Sigmodon hispidus	hispid cotton rat	CO, KS, OK	Kaufman et al. 2008, Kaufman et al. 2000, McMillan et al. 1999, Payne & Caire 1999, Clark et al. 1998, Sietman et al. 1994, Clark et al. 1987, Moulton et al. 1981, Grant & Birney 1979, Birney et al. 1976, Kaufman & Fleharty 1974
Sorex cinereus	masked shrew	IL, MN, NE, SD	Pinkert et al. 2002, Kirsch 1997, Schramm & Willcutts 1983, Grant & Birney 1979
Spermophilus spilosoma	spotted ground squirrel	CO	Moulton et al. 1981
Spermophilus tridecemlineatus	thirteen-lined ground squirrel	CO, KS, MN, NE, OK	McMillan et al. 1999, Clark et al. 1998, Kirsch 1997, Clark et al. 1987, Moulton et al. 1981, Grant & Birney 1979, Birney et al. 1976, Kaufman & Fleharty 1974
Synaptomys cooperi	southern bog lemming	KS	Kaufman et al. 2008, Kaufman et al. 2000, McMillan et al. 1999, Clark et al. 1987
Zapus hudsonius	meadow jumping mouse	IL, KS, MN	McMillan et al. 1999, Clark et al. 1987, Schramm & Willcutts 1983, Grant & Birney 1979

Table A.4 Small mammal species and species richness captured in tallgrass prairies and the state they were located.

Reference(s)	Location-Site	Species Richness	Species
Birney et al. 1976	OK	11	*Blarina carolinensis, Chaetodipus hispidus, Cryptotis parva, Microtus ochrogaster, Mus musculus, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys fulvescens, Reithrodontomys montanus, Sigmodon hispidus, Spermophilus tridecemlineatus*
Clark et al. 1998	OK-upland prairie	6	*Blarina hylophaga, Cryptotis parva, Mus musculus, Peromyscus maniculatus, Reithrodontomys fulvescens, Sigmodon hispidus*
Clark et al. 1998	OK-lowland prairie	6	*Mus musculus, Oryzomys palustris, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys fulvescens, Sigmodon hispidus*
Clark et al. 1998	OK-upland mowed prairie	6	*Chaetodipus hispidus, Mus musculus, Peromyscus maniculatus, Reithrodontomys fulvescens, Sigmodon hispidus, Spermophilus tridecemlineatus*
Grant & Birney 1979	MN	8	*Blarina brevicauda, Microtus pennsylvanicus, Mus musculus, Peromyscus leucopus, Peromyscus maniculatus, Sorex cinereus, Spermophilus tridecemlineatus, Zapus hudsonius*
Grant & Birney 1979	OK	10	*Blarina carolinensis, Chaetodipus hispidus, Cryptotis parva, Microtus ochrogaster, Mus musculus, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys fulvescens, Reithrodontomys montanus, Sigmodon hispidus*
Kaufman & Kaufman 2008	KS	9	*Blarina hylophaga, Cryptotis parva, Microtus ochrogaster, Neotoma floridana, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Sigmodon hispidus, Synaptomys cooperi*
Kaufman et al. 2000	KS-UG	6	*Blarina hylophaga, Microtus ochrogaster, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Sigmodon hispidus*
Kaufman et al. 2000	KS-PG	7	*Blarina hylophaga, Microtus ochrogaster, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Sigmodon hispidus, Synaptomys cooperi*
Kaufman & Fleharty 1974	KS-III,VI,VII	9	*Chaetodipus hispidus, Microtus ochrogaster, Onychomys leucogaster, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Reithrodontomys montanus, Sigmodon hispidus, Spermophilus tridecemlineatus*
Kaufman & Fleharty 1974	KS-IV,V	4	*Chaetodipus hispidus, Microtus ochrogaster, Peromyscus maniculatus, Reithrodontomys megalotis*
Kaufman & Fleharty 1974	KS-VIII	6	*Chaetodipus hispidus, Microtus ochrogaster, Onychomys leucogaster, Peromyscus maniculatus, Reithrodontomys megalotis, Sigmodon hispidus*
Kirsch 1997	NE	8	*Blarina brevicauda, Microtus ochrogaster, Microtus pennsylvanicus, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Sorex cinereus, Spermophilus tridecemlineatus*
Lemen & Clausen 1984	NE	4	*Microtus ochrogaster, Microtus pennsylvanicus, Peromyscus maniculatus, Reithrodontomys megalotis*
McMillan et al. 1999; Clark et al. 1987	KS-Konza prairie	15	*Blarina hylophaga, Chaetodipus hispidus, Cryptotis parva, Microtus ochrogaster, Microtus pinetorum, Mus musculus, Neotoma floridana, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Reithrodontomys montanus, Sigmodon hispidus, Spermophilus tridecemlineatus, Synaptomys cooperi, Zapus hudsonius*
Moulton et al. 1981	CO-Yuma Site	8	*Chaetodipus hispidus, Dipodomys ordii, Onychomys leucogaster, Perognathus flavescens, Peromyscus maniculatus, Reithrodontomys megalotis, Reithrodontomys montanus, Spermophilus tridecemlineatus*

Table A.4 (cont.) Small mammal species and species richness captured in tallgrass prairies and the state they were located.

Reference(s)	**Location-Site**	**Species Richness**	**Species**
Moulton et al. 1981	CO-Vilas Site	10	*Chaetodipus hispidus, Dipodomys ordii, Onychomys leucogaster, Perognathus flavescens, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Reithrodontomys montanus, Sigmodon hispidus, Spermophilus spilosoma*
Moulton et al. 1981	CO-Campo Site	5	*Chaetodipus hispidus, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Reithrodontomys montanus*
Payne & Caire 1999	OK-prairie	13	*Blarina hylophaga, Cryptotis parva, Microtus ochrogaster, Microtus pinetorum, Mus musculus, Neotoma floridana, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Reithrodontomys fulvescens, Reithrodontomys humulis, Reithrodontomys montanus, Sigmodon hispidus*
Pinkert et al. 2002	SD	5	*Blarina brevicauda, Microtus ochrogaster, Microtus pennsylvanicus, Peromyscus maniculatus, Sorex cinereus*
Schramm & Willcutts 1983	IL	9	*Blarina brevicauda, Microtus ochrogaster, Microtus pennsylvanicus, Mus musculus, Peromyscus leucopus, Peromyscus maniculatus, Reithrodontomys megalotis, Sorex cinereus, Zapus hudsonius*
Sietman et al. 1994	KS-native	6	*Blarina hylophaga, Geomys bursarius, Microtus ochrogaster, Peromyscus maniculatus, Reithrodontomys megalotis, Sigmodon hispidus*
Sietman et al. 1994	KS-hayfield	6	*Blarina hylophaga, Chaetodipus hispidus, Geomys bursarius, Microtus ochrogaster, Peromyscus maniculatus, Sigmodon hispidus*

Table A.5 Small mammals captured in no-till (NT) and conventionally tilled (CT) corn fields and the state they were located.

Scientific Name	Common name	Tillage System(s)	Location(s)	Reference(s)
Blarina brevicauda	northern short-tailed shrew	NT	IA, NE	Holm 1984, Young 1984
Dipodomys ordii	Ord's Kangaroo rat	CT, NT	KS, NE	Holm 1984, Fleharty & Navo 1983
Microtus ochrogaster	prairie vole	NT	IL	Beasley & McKibben 1976
Microtus pennsylvanicus	meadow vole	NT	IA	Young 1984
Microtus spp.	voles	NT	NE	Holm 1984
Mus musculus	house mouse	CT, NT, N/A	IA, IL, IN, KS, MD, NE	Castrale 1985, Holm 1984, Warburton & Klimstra 1984, Young 1984, Fleharty & Navo 1983, Stickel 1979, Whitaker 1966
Onychomys leucogaster	northern grasshopper mouse	CT, NT, N/A	IA, KS, NE, WY	Olson & Brewer 2003, Holm 1984, Young 1984, Fleharty & Navo 1983
Perognathus flavescens	plains pocket mouse	CT	KS	Fleharty & Navo 1983
Perognathus hispidus	hispid pocket mouse	CT, NT	KS, NE	Holm 1984, Fleharty & Navo 1983
Peromyscus leucopus	white-footed mouse	CT, NT, N/A	IA, IL, IN, MD, NE, PA	Block et al. 1999, Albers et al. 1990, Castrale 1985, Holm 1984, Warburton & Klimstra 1984, Young 1984, Whitaker 1966
Peromyscus maniculatus	deer mouse	CT, NT, N/A	CO, IA, IL, IN, KS, NE, WY	Olson & Brewer 2003, Sterner et al. 2003, Block et al. 1999, Clark & Young 1986, Castrale 1985, Holm 1984, Warburton & Klimstra 1984, Young 1984, Fleharty & Navo 1983, Whitaker 1966
Reithrodontomys megalotis	western harvest mouse	CT, NT	IA, KS, NE	Holm 1984, Young 1984, Fleharty & Navo 1983
Reithrodontomys montanus	plains harvest mouse	N/A	WY	Olson & Brewer 2003
Sigmodon hispidus	hispid cotton rat	CT	KS	Fleharty & Navo 1983
Sorex cinereus	masked shrew	NT	IA	Young 1984
Spermophilus spilosoma	spotted ground squirrel	CT	KS	Fleharty & Navo 1983
Spermophilus tridecemlineatus	thirteen-lined ground squirrel	CT, NT	IA, NE	Clark & Young 1986, Holm 1984, Young 1984
Synaptomys cooperi	bog lemmings	NT	IL	Beasley & McKibben 1976
Zapus hudsonius	meadow jumping mouse	NT	IA	Young 1984

Table A.6 Stand management practices for the three habitats at each location with the application rates and time for each treatment: fertilizer, lime, herbicide applications.

Farm	Habitat	Inter-seeding	Fertilizer	Lime	Herbicide
Boyd_S	Corn	N/A	120 kg/ha of nitrogen (mid-May)	-	1540 mL/ha of glyphosate (mid-May)
	Hay	-	-	-	-
	Switchgrass	N/A	67 kg/ha of actual nitrogen (mid-May)	-	-
Fayette	Corn	N/A	165 kg/ha of nitrogen (4/24/2009)	-	1540 mL/ha of glyphosate (4/24/2009)
	Hay	9 kg/ha of orchardgrass and bluegrass 3:2 mix (May)	125 kg/ha of urea (May)	-	-
	Switchgrass	N/A	67 kg/ha of actual nitrogen (mid-May)	-	-
Lewis	Corn	N/A	230 kg/ha of 19-19-19 (late-April)	-	1540 mL/ha of glyphosate (late-April)
	Hay	-	56 kg/ha of actual nitrogen (May)	112 kg/ha (May)	-
	Switchgrass	N/A	56 kg/ha of actual nitrogen (mid-May)	112 kg/ha (May)	-
Boyd_N	Corn	N/A	90 kg/ha of nitrogen (early-May) 23 kg/ha potash (early-May) 23 kg/ha phosphate (early-May)	6,740 kg/ha (early-May)	1540 mL/ha of glyphosate (early-May) 585 mL/ha of 2,4-D (late-May)
	Hay	-	-	-	-
	Switchgrass	N/A	67 kg/ha of actual nitrogen (early-May)	112 kg/ha (early-May)	1540 mL/ha of glyphosate (late-May)

Table A.7 Sex ratio (Female:Male) for species within habitat and trapping session.

Trapping session	Habitat	*P. leucopus* F:M	*P. maniculatus* F:M	*M. musculus* F:M	*Microtus* spp. F:M
Spring	Corn	1:1	1:7	0:1	0:0
	Hay	0:3	0:1	1:2	0:0
	Switchgrass	3:12	1:4	0:0	0:0
Summer	Corn	20:22	14:19	15:5	0:0
	Hay	1:0	0:1	0:0	4:4
	Switchgrass	24:28	1:2	2:1	9:5
Fall	Corn	10:14	6:8	3:1	0:0
	Hay	0:0	0:0	0:0	6:8
	Switchgrass	16:22	0:0	17:12	25:24
Winter	Corn	3:0	5:3	0:0	0:0
	Hay	0:0	15:1	0:0	1:0
	Switchgrass	23:15	21:1	2:1	0:0

Table A.8 Presence of lactating females by species captured in the corn habitat organized by trapping session and farm.

Trapping session	Fayette No-till	Lewis Conventional Till	Boyd_N No-till	Boyd_S Conventional Till
Spring	.	.	.	.
Summer	*P. leucopus*	*M. musculus*	.	.
Fall	*P. maniculatus bairdii*	*P. leucopus*	*P. leucopus*	*M. musculus*
Winter	.	.	.	.

Table A.9 Presence of lactating females by species captured in the hay habitat organized by trapping session and farm.

Trapping session	Fayette	Lewis	Boyd_N	Boyd_S
Spring	.	.	.	.
Summer	.	*Microtus* spp.	.	.
Fall	.	.	.	.
Winter	.	.	.	.

Table A.10 Presence of lactating females by species captured in the switchgrass habitat organized by trapping session and farm.

Trapping session	Fayette 3-year stand	Lewis 3-year stand	Boyd_N 2-year stand	Boyd_S 2-year stand
Spring	*P. leucopus*	.	.	.
Summer	*P. leucopus* *P. maniculatus bairdii*	.	.	.
Fall	*P. leucopus*	*P. leucopus*	.	.
Winter	.	.	.	.

Table A.11 Botanical species composition (%) for the corn habitats within each farm and trapping session.

Trapping session	Farm	Component	Composition (%)
Spring	Boyd_S	Corn	0
		Debris	0
		Misc. Weeds	1
		Bare Soil	99
	Fayette	Corn	-
		Debris	-
		Misc. Weeds	-
		Bare Soil	-
	Lewis	Corn	3
		Debris	0
		Misc. Weeds	0
		Bare Soil	97
	Boyd_N	Corn	2
		Debris	0
		Misc. Weeds	0
		Bare Soil	98
Summer	Boyd_S	Corn	16
		Debris	0
		Misc. Weeds	9
		Bare Soil	75
	Fayette	Corn	-
		Debris	-
		Misc. Weeds	-
		Bare Soil	-
	Lewis	Corn	13
		Debris	0
		Misc. Weeds	2
		Bare Soil	86
	Boyd_N	Corn	17
		Debris	0
		Misc. Weeds	18
		Bare Soil	66
Fall	Boyd_S	Corn	11
		Debris	0
		Misc. Weeds	2
		Bare Soil	88
	Fayette	Corn	13
		Debris	0
		Misc. Weeds	13
		Bare Soil	74
	Lewis	Corn	13
		Debris	0
		Misc. Weeds	2
		Bare Soil	86

Table A.11 (cont.) Botanical species composition of the corn habitat within farm and trapping session.

Trapping Session	Farm	Component	Composition (%)
Fall	Boyd_N	Corn	12
		Debris	0
		Misc. Weeds	6
		Bare Soil	83
Winter	Boyd_S	Corn	0
		Debris	65
		Misc. Weeds	16
		Bare Soil	19
	Fayette	Corn	2
		Debris	63
		Misc. Weeds	0
		Bare Soil	35
	Lewis	Corn	9
		Debris	77
		Misc. Weeds	3
		Bare Soil	11
	Boyd_N	Corn	6
		Debris	13
		Misc. Weeds	35
		Bare Soil	47

Table A.12 Botanical species composition (%) for the hay habitats within each farm and trapping session.

Trapping session	Farm	Component	Composition (%)
Spring	Boyd_S	Tall Fescue	34
		Orchardgrass	28
		KY Bluegrass	0
		Alfalfa	0
		Timothy	0
		Red Clover	0
		White Clover	15
		Hop Clover	0
		Dead Material	0
		Misc. Weeds	23
		Bare Soil	0
	Fayette	Tall Fescue	-
		Orchardgrass	-
		KY Bluegrass	-
		Alfalfa	-
		Timothy	-
		Red Clover	-
		White Clover	-
		Hop Clover	-
		Dead Material	-
		Misc. Weeds	-
		Bare Soil	-

Table A.12 (cont.) Botanical species composition (%) for the hay habitats within each farm and trapping session.

Trapping Session	Farm	Component	Composition (%)
Spring	Lewis	Tall Fescue	39
		Orchardgrass	21
		KY Bluegrass	0
		Alfalfa	0
		Timothy	0
		Red Clover	9
		White Clover	0
		Hop Clover	19
		Dead Material	0
		Misc. Weeds	12
		Bare Soil	0
	Boyd_N	Tall Fescue	3
		Orchardgrass	24
		KY Bluegrass	0
		Alfalfa	37
		Timothy	5
		Red Clover	30
		White Clover	0
		Hop Clover	0
		Dead Material	0
		Misc. Weeds	1
		Bare Soil	0
Summer	Boyd_S	Tall Fescue	28
		Orchardgrass	23
		KY Bluegrass	3
		Alfalfa	0
		Timothy	0
		Red Clover	0
		White Clover	20
		Hop Clover	0
		Dead Material	0
		Misc. Weeds	3
		Bare Soil	23
	Fayette	Tall Fescue	-
		Orchardgrass	-
		KY Bluegrass	-
		Alfalfa	-
		Timothy	-
		Red Clover	-
		White Clover	-
		Hop Clover	-
		Dead Material	-
		Misc. Weeds	-
		Bare Soil	-

Table A.12 (cont.) Botanical species composition (%) for the hay habitats within each farm and trapping session.

Trapping Session	Farm	Component	Composition (%)
Summer	Lewis	Tall Fescue	48
		Orchardgrass	18
		KY Bluegrass	13
		Alfalfa	1
		Timothy	0
		Red Clover	4
		White Clover	0
		Hop Clover	0
		Dead Material	0
		Misc. Weeds	11
		Bare Soil	5
	Boyd_N	Tall Fescue	0
		Orchardgrass	15
		KY Bluegrass	0
		Alfalfa	22
		Timothy	15
		Red Clover	12
		White Clover	0
		Hop Clover	0
		Dead Material	0
		Misc. Weeds	18
		Bare Soil	19
Fall	Boyd_S	Tall Fescue	18
		Orchardgrass	21
		KY Bluegrass	14
		Alfalfa	0
		Timothy	0
		Red Clover	2
		White Clover	36
		Hop Clover	0
		Dead Material	0
		Misc. Weeds	3
		Bare Soil	8
	Fayette	Tall Fescue	8
		Orchardgrass	4
		KY Bluegrass	34
		Alfalfa	0
		Timothy	0
		Red Clover	6
		White Clover	0
		Hop Clover	0
		Dead Material	0
		Misc. Weeds	38
		Bare Soil	10

Table A.12 (cont.) Botanical species composition (%) for the hay habitats within each farm and trapping session.

Trapping Session	Farm	Component	Composition (%)
Fall	Lewis	Tall Fescue	28
		Orchardgrass	27
		KY Bluegrass	26
		Alfalfa	1
		Timothy	0
		Red Clover	7
		White Clover	0
		Hop Clover	0
		Dead Material	0
		Misc. Weeds	12
		Bare Soil	1
	Boyd_N	Tall Fescue	0
		Orchardgrass	23
		KY Bluegrass	2
		Alfalfa	25
		Timothy	0
		Red Clover	18
		White Clover	2
		Hop Clover	0
		Dead Material	0
		Misc. Weeds	6
		Bare Soil	25
Winter	Boyd_S	Tall Fescue	42
		Orchardgrass	22
		KY Bluegrass	20
		Alfalfa	0
		Timothy	0
		Red Clover	0
		White Clover	15
		Hop Clover	0
		Dead Material	0
		Misc. Weeds	2
		Bare Soil	0
	Fayette	Tall Fescue	18
		Orchardgrass	4
		KY Bluegrass	36
		Alfalfa	0
		Timothy	0
		Red Clover	0
		White Clover	13
		Hop Clover	0
		Dead Material	0
		Misc. Weeds	19
		Bare Soil	10

Table A.12 (cont.) Botanical species composition (%) for the hay habitats within each farm and trapping session.

Trapping Session	Farm	Component	Composition (%)
Winter	Lewis	Tall Fescue	56
		Orchardgrass	8
		KY Bluegrass	12
		Alfalfa	0
		Timothy	0
		Red Clover	0
		White Clover	7
		Hop Clover	0
		Dead Material	0
		Misc. Weeds	6
		Bare Soil	13
	Boyd_N	Tall Fescue	2
		Orchardgrass	43
		KY Bluegrass	9
		Alfalfa	6
		Timothy	0
		Red Clover	3
		White Clover	8
		Hop Clover	0
		Dead Material	4
		Misc. Weeds	6
		Bare Soil	18

Table A.13 Botanical species composition (%) for the switchgrass habitats within each farm and trapping session.

Trapping Session	Farm	Component	Composition (%)
Spring	Boyd_S	Switchgrass	3
		Debris	0
		Foxtail	0
		Misc. Weeds	57
		Bare Soil	41
	Fayette	Switchgrass	-
		Debris	-
		Foxtail	-
		Misc. Weeds	-
		Bare Soil	-
	Lewis	Switchgrass	43
		Debris	0
		Foxtail	0
		Misc. Weeds	52
		Bare Soil	5
	Boyd_N	Switchgrass	2
		Debris	0
		Foxtail	0
		Misc. Weeds	7
		Bare Soil	92

Table A.13 (cont.) Botanical species composition (%) for the switchgrass habitats within each farm and trapping session.

Trapping Session	Farm	Component	Composition (%)
Summer	Boyd_S	Switchgrass	45
		Debris	0
		Foxtail	39
		Misc. Weeds	8
		Bare Soil	8
	Fayette	Switchgrass	-
		Debris	-
		Foxtail	-
		Misc. Weeds	-
		Bare Soil	-
	Lewis	Switchgrass	83
		Debris	0
		Foxtail	0
		Misc. Weeds	2
		Bare Soil	15
	Boyd_N	Switchgrass	20
		Debris	0
		Foxtail	65
		Misc. Weeds	13
		Bare Soil	4
Fall	Boyd_S	Switchgrass	33
		Debris	0
		Foxtail	62
		Misc. Weeds	0
		Bare Soil	6
	Fayette	Switchgrass	100
		Debris	0
		Foxtail	0
		Misc. Weeds	0
		Bare Soil	0
	Lewis	Switchgrass	93
		Debris	0
		Foxtail	3
		Misc. Weeds	1
		Bare Soil	3
	Boyd_N	Switchgrass	53
		Debris	0
		Foxtail	23
		Misc. Weeds	20
		Bare Soil	3

Table A.13 (cont.) Botanical species composition (%) for the switchgrass habitats within each farm and trapping session.

Trapping Session	Farm	Component	Composition (%)
Winter	Boyd_S	Switchgrass	16
		Debris	18
		Foxtail	0
		Misc. Weeds	14
		Bare Soil	52
	Fayette	Switchgrass	22
		Debris	62
		Foxtail	0
		Misc. Weeds	0
		Bare Soil	17
	Lewis	Switchgrass	33
		Debris	0
		Foxtail	0
		Misc. Weeds	3
		Bare Soil	63
	Boyd_N	Switchgrass	21
		Debris	2
		Foxtail	0
		Misc. Weeds	5
		Bare Soil	73

Table A.14 Summary of Robel pole and weighted average height measurements for corn, hay, and switchgrass habitats within farm and trapping session.

Trapping Session	Farm	Habitat	Robel Pole (cm)	Weighted Ave. Height (cm)
Spring	Boyd_S	Corn	-	0
		Hay	-	104.0
		Switchgrass	-	8.3
	Fayette	Corn	-	-
		Hay	-	-
		Switchgrass	-	-
	Lewis	Corn	-	0.3
		Hay	-	74.0
		Switchgrass	-	70.1
	Boyd_N	Corn	-	0.1
		Hay	-	58.0
		Switchgrass	-	0.6
Summer	Boyd_S	Corn	6.7	46.5
		Hay	1.1	15.4
		Switchgrass	11.3	101.9
	Fayette	Corn	-	-
		Hay	-	-
		Switchgrass	-	-
	Lewis	Corn	6.4	41.1
		Hay	3.5	34.4
		Switchgrass	19.8	129.8

Table A.14 (cont.) Summary of Robel pole and weighted average height measurements for corn, hay, and switchgrass habitats within farm and trapping session.

Trapping Session	Farm	Habitat	Robel Pole (cm)	Ave. Weighted Height (cm)
Summer	Boyd_N	Corn	24.2	90.0
		Hay	1.5	21.3
		Switchgrass	7.5	92.2
Fall	Boyd_S	Corn	4.0	31.6
		Hay	1.3	19.5
		Switchgrass	10.0	77.7
	Fayette	Corn	9.2	37.2
		Hay	0.6	8.4
		Switchgrass	12.2	122.0
	Lewis	Corn	6.3	39.4
		Hay	2.4	28.8
		Switchgrass	8.7	134.0
	Boyd_N	Corn	9.2	28.3
		Hay	1.4	14.0
		Switchgrass	14.5	120.2
Winter	Boyd_S	Corn	0.5	3.8
		Hay	0.8	14.8
		Switchgrass	0.5	3.5
	Fayette	Corn	0.5	6.0
		Hay	0.5	5.5
		Switchgrass	0.9	7.5
	Lewis	Corn	1.6	5.7
		Hay	1.0	14.2
		Switchgrass	0.9	5.4
	Boyd_N	Corn	0.5	1.9
		Hay	0.8	12.0
		Switchgrass	0.7	3.6

VITA

The author, Laura Jane Mary Schwer, was born on November 22, 1985 in Chicago, Illinois to William and Mary Jane Peterman. She was raised in Chicago, Illinois until 10 years old when she moved an hour south to the rural suburbs. She began riding horses and working on nearby farms at 13 years old, which added to her appreciation of the great outdoors and her love for animals. She graduated from Peotone High School in May of 2004 and pursued a Bachelor's degree in Natural Resources and Environmental Sciences concentrating in Fish and Wildlife Conservation at the University of Illinois Urbana-Champaign in August of 2004. She graduated with high honors from the University of Illinois in May of 2008 and shortly afterwards married, Donald Schwer, on June 14, 2008. They moved to the University of Kentucky in August of 2008 and she began working as a Senior Laboratory Technician and Assistant Coordinator of the UK Pasture Evaluation Program in the Plant and Soil Science Department under Dr. S. Ray Smith in September of 2008. In addition to her staff position, she began pursuing a Master's of Science degree in Crop Science at the University of Kentucky in January of 2009 with Dr. S. Ray Smith as her main advisor.