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A Floristic Study of the Oak Leaf Lake Unit of the Swan Lake Wildlife Management Area in Nicollet County, Minnesota

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By

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Prairies play an integral ecological role, protecting biodiversity and providing habitat for fauna. The number of prairie acres has significantly declined in Minnesota, making the existing prairies that much more valuable. The Oak Leaf Lake Unit of the Swan Lake Wildlife Management Area in Nicollet County, Minnesota (latitude 44.311050, longitude -94.015577) was purchased by the Minnesota Department of Natural Resources in 1994 and is being managed as tallgrass prairie. Floristic surveys were performed during the 2011 and 2012 growing seasons to gather baseline data. These data were used to assess the quality of the site through calculation of various indices that allowed comparison of its flora to floras of other prairies in the area. Two sampling methods, a walk-through method and a random-sampling-in-quadrats method, were employed to compare the effectiveness of data compilation (i.e. the number of plant species located and identified) for each method. Additional data collected via the random-sampling-in-quadrats method included percent cover, litter depth, frequency, and species diversity. In total, 112 plant species in 88 genera and 33 families were found over both growing seasons with nearly

half found exclusively using the walk-through method in 2011 and none found exclusively using the random-sampling-in-quadrats method in 2012. The percentage of native, nonnative, and unknown species located in each sampling method were similar. No rare or endangered species were located. Differences in the sampling methods make determining the most effective and efficient method difficult. The most effective method is determined predominantly by the goals and restrictions of each distinct study. For the purposes of this particular study, the walk-through method produced a more complete compilation of plant species data than the random-sampling-in-quadrats method. The data gathered through this study provides important information on the current ecological quality of the Oak Leaf Lake Unit while providing a baseline for future research at the site.

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INTRODUCTION

Prairies play an integral ecological role. They are essential in protecting biodiversity and are a necessary habitat for fauna. Prairie floras exist under diverse growing conditions and niches.

A floristic study and analysis of the Oak Leaf Lake Unit of the Swan Lake Wildlife Management Area was performed to gather baseline data and to compare two sampling techniques. Baseline data are needed because little floristic information exists for this site and will be beneficial for management and future research. Two different plant sampling techniques were employed to compare and contrast the effectiveness of the techniques. The first technique employed a walk-through method, where the study site was thoroughly walked through on 13 occasions and specimens of all plant species found were collected as vouchers. The second technique employed a random-sampling-in-quadrats method that only recorded species found within 1 m^2 quadrats located randomly throughout the site. The efficacy of one sampling technique over the other is often debated. Species richness and distinctiveness of the plant species collected were analyzed for each method to rank the effectiveness of each method. Findings indicated each sampling method had strengths and weaknesses. The plant species and vegetation found at Oak Leaf Lake are essential in determining the ecological quality of the site.

Prairies in Minnesota

Earth is divided into major ecological regions called biomes, which are classified by their vegetation, which is controlled by climate, topography, proximity to large bodies of water, soil, and other factors (Carpenter 1940; Dice 1962; Tester 1995). Three biomes occur in Minnesota: coniferous forest, deciduous forest, and prairie. (Figure 1) (MN DNR 1993; Tester 1995).

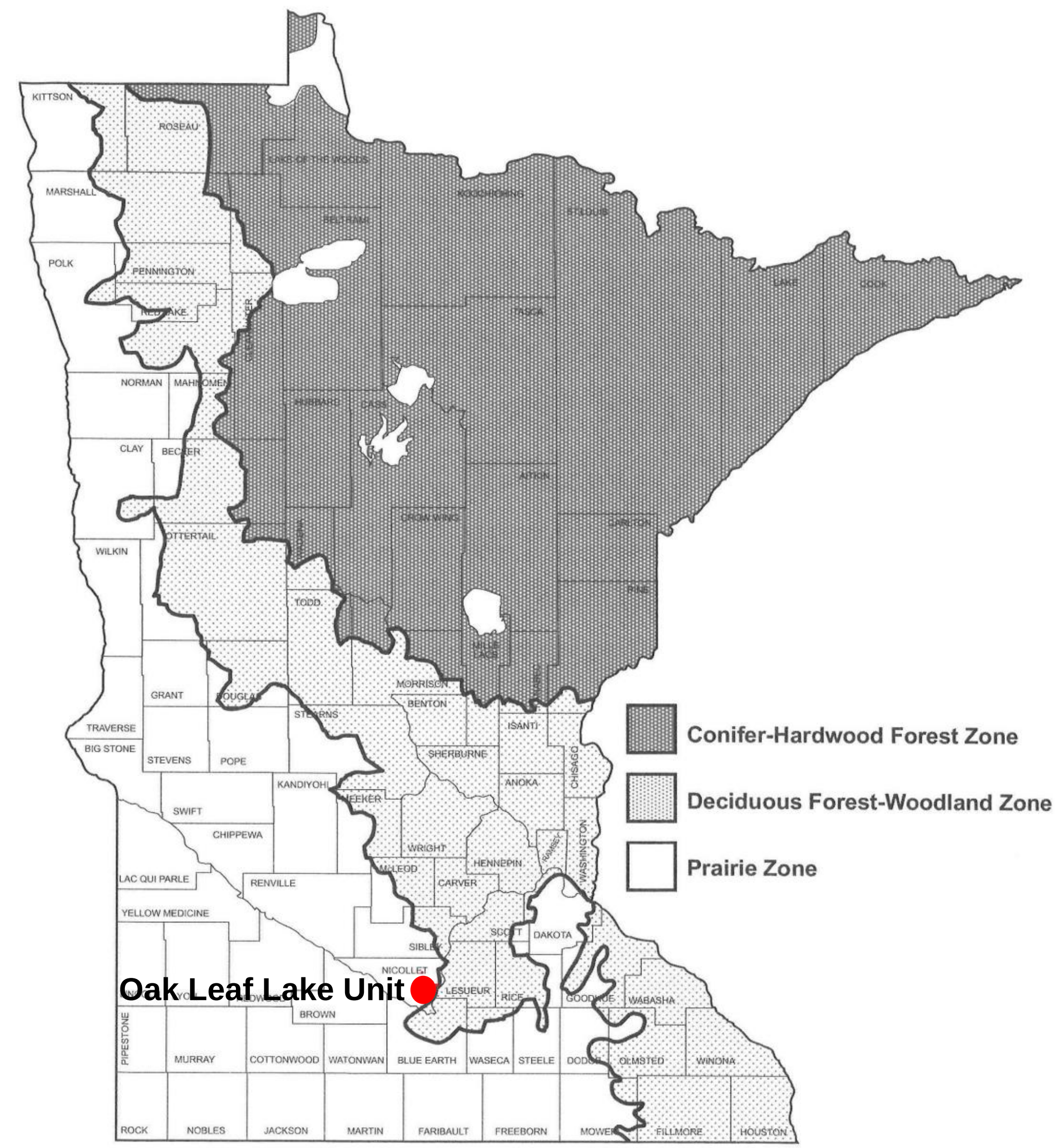

Figure 1. The three biomes in Minnesota: coniferous forest, deciduous forest, and prairie. The study area is located at the transitional area, or ecotone, of the deciduous forest and prairie biomes (from MN DNR, *Minnesota's native vegetation: a key to natural communities,* version 1.5. Copyright © 1993 by State of Minnesota, MN DNR. Reprinted by permission of MN DNR).

Physical environmental factors, such as temperature and precipitation, drive the development and succession of biomes and communities (Dice 1962). Low precipitation and warm summers and cold winters were instrumental in the development of the prairies of southwestern and southcentral Minnesota (Carpenter 1940; Tester 1995), where the Oak Leaf Lake Unit is located. Frost also shapes communities as it can affect the growing season by injuring, delaying growth, or killing individuals (Dice 1962).

Coniferous forest is found in northeast Minnesota where average annual temperatures range between 2.2 and 5° C and average annual rainfall is 45.7 to 50.8 cm (MN DNR 2016a). It is dominated by *Pinus strobus* (white pine), *P. resinosa* (red pine), *Picea* spp. (spruce), *Abies* spp. (fir), *Populus* spp. (aspen), and *Betula* spp. (birch) (Tester 1995). Deciduous forest occurs in a narrow diagonal band running from the northwest to the southeast where average annual temperatures range between 3.9 and 7.2° C and average annual rainfall is 40.6 to 45.7 cm (MN DNR 2016a). It consists mainly of hardwoods including *Acer* spp. (maple), *Tilia* spp. (basswood), and *Quercus* spp. (oak) in upland areas; low, wetter areas support *Ulmus* spp. (elm) and *Acer* spp. (maple) (Curtis 1971; Tester 1995). Prairie occurs in the west from Canada to Iowa where average annual temperatures range between 2.8 and 7.2° C and average annual rainfall is 35.6 to 40.6 cm (MN DNR 2016a); it extends further east in the central and southern portion of the State where annual precipitation would support deciduous forest. In this region prairies were usually maintained by periodic fires. Prairie is mostly made up of herbaceous plants, often divided into two informal groups: grasses (grass and grass-like species) and forbs (non-grass-like species) (Tester 1995). The study site is located on the eastern edge of the prairie biome near the ecotone (the transitional area between two biomes or communities [Carpenter 1940; Dice 1962]) of the prairie biome and the deciduous forest biome. The ecotone between the prairie and deciduous forest is often brush prairie, consisting of areas of small trees, low shrubs, and herbaceous species, or savanna, consisting of scattered trees with herbaceous species underneath (Tester 1995).

Minnesota was once home to more than 7.28 million ha of native prairie (Marschner 1974), but now, less than two percent, roughly 95,100 ha, remains (MN DNR 2010; MPPWG 2011). Seven primary threats to the remaining native prairie and associated habitat have been identified by the Minnesota Prairie Plan Working Group (MPPWG 2011): 1) continued loss of prairie and wetlands to conversion, development, and destruction, 2) invasive species, 3) detrimental grazing practices, 4) woody plant encroachment, 5) energy development, 6) atmospheric nitrogen deposition, and 7) change in climate. Many prairies are too fragmented and too small to provide adequate habitat for many species (Higgins el al. 2001; MPPWG 2011), thus threatening sustained biodiversity (Gibbs et al. 2008).

Human activity is primarily responsible for the destruction of most of Minnesota's native prairie. Land was cleared predominantly for agricultural use and urban development (Samson et al. 2004). Approximately 1.27 million ha of restored prairie exists in Minnesota; of that, 647,500 ha are enrolled in the United States Department of Agriculture's (USDA) Conservation Reserve Program (CRP) (BWSR 2010). Nearly 44 percent of those 647,500 CRP ha (over 284,500 ha) expired or will expire in Minnesota between September 2014 and September 2018 (USDA 2014). Once expired, landowners, for the most part, are free to do what they wish with their CRP property, including destroying the prairie established with their CRP contract.

Prior to European settlement, prairies of south-central Minnesota were maintained by disturbances of fire, changes in weather (i.e. drought), and grazing by large herbivores, mainly bison (Samson et al. 2004; MPPWG 2011). Fires were either naturally-occurring, usually ignited by lightning, or intentionally set by humans who routinely used fire to clear out old, dead plant debris to promote new plant growth (Samson et al. 2004). Prairie fires usually moved eastward, driven by southwestern winds, until they reached the forest and died out, due to greater moisture and less easily ignitable fuel (Tester 1995). The deciduous forest was limited in its spread westward by prairie fire; thus, fire played a role in the development of the ecotone between the prairie and deciduous forest (Tester 1995).

Prairie Characteristics

Prairies are diverse communities dominated by herbaceous perennials, species that store starch in extensive roots and/or underground stems (rhizomes), and/or in modified underground stems (bulbs, corms, tubers, etc.) (Raven et al. 2005; Solomon et al. 2005). In temperate regions, aerial stems die to the ground each fall. The plants overwinter underground on stored reserves in their "perennating organs" (roots, rhizomes, bulbs, corms, tubers, etc.). In spring, buds on perennating organs begin to develop to produce new sets of aerial stems, leaves, and, eventually, reproductive structures. In contrast to shrubs and trees, which produce wood that requires high-energy input but is not photosynthetic, the entire aerial shoot system of herbaceous perennials is mostly photosynthetic, making prairies among the most productive biomes on the planet (Kline 2005; Raven et al. 2005; Solomon et al. 2005).

Prairie species are adapted to extremes of temperature (daily and seasonal), high light intensity, desiccating winds, grazing, fire, drought, and often, nutrient-poor soils (Tester 1995; Kline 2005; Gendron and Wilson 2007). Most share abilities to 1) grow quickly under a wide range of conditions, such as varying levels of moisture and nitrogen availability, 2) reproduce asexually (vegetatively/clonally) by rhizomes or roots that are protected from aboveground disturbances such as fire and grazing, 3) reproduce sexually through the production of numerous seeds to increase probability of regeneration (Grilz and Romo 1994; Gendron and Wilson 2007; USDA 2012c; Tompkins et al. 2013). Grasses, in particular, take advantage of wind for both pollination and seed dissemination (Kline 2005).

The Asteraceae (sunflower), Poaceae (grass), and Fabaceae (legume), respectively, are the best-represented families in prairies (Dix and Butler 1960; Kline 2005). Prairies are dominated by grasses, both in biomass and cover, however they do not contribute the most to prairie plant diversity. Ladd (2005) provides a list of 988 tallgrass prairie species. Annual and perennial sedges and grasses make up about 20 percent of the species. Among the most common native true grasses in drier Midwestern prairies are *Schizachyrium scoparium* (little bluestem), *Bouteloua curtipendula* (side-oats grama), *Sporobolis heterolepis* (prairie dropseed), and *Stipa spartea* (porcupine grass) (Tester 1995; Kline 2005). In deep silt-loam soils of dry to mesic sites *Andropogon* *gerardii* (big bluestem) and *Sorghastrum nutans* (Indian grass) are very common; in wetter sites one finds *Calamagrostis canadensis* (blue joint grass) and *Spartina pectinata* (prairie cord grass) (Tester 1995; Kline 2005). Commonly abundant nonnative perennial grasses include *Bromus inermis* (smooth brome) (Grilz and Romo 1994) and *Poa pratensis* (Kentucky bluegrass), which forms a dense sod once established; it is often included in seed mixes used to stabilize roadsides (USDA 2012c). Forbs provide the diversity on prairies, making up as much as 70 percent of species on a site (Ladd 2005); they are usually abundant, with their composition varying with soil depth, moisture, and the age of the site (Kline 2005). Charismatic prairie species are found in *Symphyotrichum* (aster [formerly genus *Aster*]), *Solidago* (goldenrod), *Ratibida* and *Rudbeckia* (coneflowers), *Helianthus* (sunflower), *Asclepias* (milkweed), *Monarda* (mints), to name only a few genera (Curtis 1971; Tester 1995; Kline 2005; USDA 2012c).

In mature prairies, species are usually long-lived, slow-growing, late-successional perennials that grow close together, reducing the likelihood that invasive species can become established (Kline 2005). In young or disturbed, low-quality prairies, short-lived, fast-growing, early-successional annuals can often be found.

Site Description

The Oak Leaf Lake Unit is located in the northern half of section 25 of Oshawa Township (T110N R27W) in Nicollet County about 2 km west of Saint Peter, Minnesota (latitude 44.311050, longitude -94.015577) (Figure A1) in an area where, historically, prairies (maintained by fire) and maple-basswood climax vegetation formed patches on the landscape. The 25.9 ha unit comprises a 4.78 ha lake that is a resting and feeding location for migratory birds, 0.24 ha of deciduous forest, 3.08 ha of seasonally-flooded emergent vegetation, and 17.80 ha of restored tallgrass prairie, which was seeded with prairie grasses and forbs (MN DNR 2012b). The land surrounding the unit includes a farm site to the east and rotational cropland planted predominantly to corn and soybeans (Figure A2).

The unit was purchased by the MN DNR in September 1994 to become "part of the Swan Lake Wildlife Management Area and to be managed for waterfowl nesting cover, upland game bird nesting cover, nongame use, prairie propagation and public recreation" (MN DNR 2011). Some of the wildlife documented at the unit include mallards, teals, wood ducks, great blue herons, egrets, shore birds, gulls, pheasants, muskrats, and white-tailed deer (MN DNR 2011). Artificial nest structures were in place in the past, including mallard baskets, wood duck boxes, round bales for geese, and bluebird houses (MN DNR 2011), and some are still in place. Hunting is allowed at the unit.

There are 1.05 ha of wetlands located on the east side of the site classified as Type 4 wetlands, which are inland deep fresh marshes that usually have soils covered with 15 cm to 0.9 m of water during the spring and summer and support species like cattails, reeds, bulrushes, spike-rushes, and wild rice (BWSR n.d.). Type 4 wetlands often fill shallow lake basins or potholes or border open water. In the case of this study site, the wetlands border the open water of Oak Leaf Lake.

The study site consists of a portion of the Oak Leaf Lake Unit of approximately 6.95 ha on the northern end of the unit, along the northern shoreline of the lake (Figure B1).

Geology

Three different rock layers of three different ages underlie the study site (Jackson 1994; Ellingson 2000). Granite, gneiss, and quartzite are the primary components of the oldest layer from the Precambrian Period, approximately 1.5 to 3 billion years ago. The second layer, deposited about 570 to 480 million years ago during the Paleozoic Period, consists of sandstone and dolomite. The third layer, the surficial layer made up of loamy till, was left behind by the region's most recent Wisconsin Period glaciers about 12,000 years ago (Jackson 1994; Ellingson 2000). As the glaciers advanced, retreated, or melted, glacial sediments, a mixture of clay, silt, sand, gravel, cobbles, and boulders, were deposited, creating a topography of gently sloping to nearly level "ground moraines" (Jackson 1994; Ellingson 2000). Erosion of these moraines created the landscape we know today. Glacial sediments found at the study site are classified as Gently Rolling Ground Moraine Sediments (Jackson 1994; Ellingson 2000).

Soils

Soil is a mixture of inorganic and organic particles in which plants grow. Soils can differ greatly in organic matter, texture, pH, and depth and therefore play an important, but varied, role in the development of biomes and communities (Dice 1962).

Soil texture is defined by the percentages of sand (particles with diameters between 2 and 0.5 mm), silt (with diameters between 0.5 and 0.002 mm), and clay (with diameters less than 0.002 mm) (Dice 1962). Larger-sized particles, such as gravel (with diameters greater than 2 mm), pebbles, and cobbles may also be present. Soils with larger particle diameters often have more open spaces and can better allow plant roots and rainfall to penetrate (Dice 1962). Particle size also affects evaporation rates, water retention, and rates of oxygen and carbon dioxide diffusion; these factors, along with climate, affect the type of biome or community that develops (Dice 1962).

Most prairie soils are covered with a layer of plant litter, which is the dead plant material that has fallen to the ground and is an essential part of the nutrient cycle and soil health (Collins and Wallace 1990). Litter can foster plant growth by providing appropriate moisture, temperature, and soil nitrate levels for increased seed germination (Myster 2006). But litter can also deter plant growth by physically blocking seedlings, obstructing sunlight, or providing conditions that promote fungal growth (Carson and Peterson 1990; Higgins et al. 2001; Myster 2006). Litter depth is a measurement of the accumulated plant litter that, once decomposed, becomes organic matter in the soil and provides nutrients for plant uptake (Myster 2006).

According to the USDA, no highly erodible land exists on the site (USDA n.d.). The highest elevation of the grassland area is approximately 305 m and slopes down to its lowest level, 301 m, at the lake. An analysis of USDA soil maps shows four types of soils found at the site (Table C1). The western half from the driveway and parking lot to the middle consists of 109–Cordova clay loam (fine loamy) (Figure B1). The middle portion on the eastern side consists of 239–Le Sueur clay loam (fine loamy). The northwest portion and the middle of the eastern half consists of 978–Cordova-Rolfe complex (fine loamy). The shoreline consists of 1075–Klossner and Muskego soils, ponded (loamy). The organic matter content is highest in the 1075–Klossner and Muskego soils, with 25 to 60 percent, while the other three soil types have an organic matter percentage ranging from two to seven. The decomposition of the prairie plant roots and the litter produced every year by the prairie vegetation contribute organic matter and nutrients to the soil (Tester 1995). All four soil types found at the study site have slopes ranging from zero to three percent, are classified as very-poorly-drained to somewhat-poorly-drained, and have a high- to very-high available water capacity. The amount of water the soil can store that is available for plant use is based partly on soil particle size and soil compaction (Dice 1962). The roots of plants are not able to extract all of the water in the soil and each plant species is able to extract water at different rates depending on their water needs, root system, and transpiration rate (Dice 1962). The least porous layers of all four soil types have moderately low to moderately high capacities to transmit water (capacity is determined by how much water in inches can be transmitted per hour).

Hydrology

Aquifers consist of a permeable layer or layers of rock and/or sand that can hold water. Many aquifers are found in eastern Nicollet County where the Oak Leaf Lake Unit is located. The aquifers are located within the sandstone from the Precambrian and

Paleozoic eras and contain water with high concentrations of iron, sulfate, and dissolved minerals leached from the sandstone (Jackson 1994).

Two small marsh wetlands, one on the northeast side of the lake and the other located west of the lake, drain into the lake. The northeast wetland is located within the study site and the west wetland is outside of the study site boundaries. Several small springs flow into the lake on the northeast side, but the major source of water for the lake is local runoff (MN DNR 2011). The surrounding land has a cropping history of corn and wild rice and contains drainage tile near the lake but due to poor records, the exact location of the tile is unknown. Records do indicate, however, approximately 2,100 m of tile were present in 1982 in parcels adjacent to the site (MN DNR 2011). The lake contains no outlet, limiting the potential for extreme changes in water levels and possibly retarding the growth of emergent vegetation (MN DNR 2011). The lake is currently classified as a "protected public water" under the Protected Waters Inventory Classification (MN DNR 2011).

Previous Site Surveys

A 1953 survey of the site was carried out on July 14 and 15; it focused on Oak Leaf Lake (MN DNR 2011), which was described as a semi-permanent waterfowl and muskrat lake approximately 85.7 ha in size with 2.3 km of shoreline. The survey (MN DNR 2011) noted the following: the maximum depth of the lake was 1.7 m and mean depth was 1.2 to 1.4 m. The lake bottom was predominantly firm mud. Of the 24 aquatic plant species identified, 10 were emergent (the plant is rooted in water, but the majority of the plant extends out of the water), with eight native and two of unknown origin, and 14 were submergent (the majority of the plant, if not all, grows under the water's surface), with 12 native and two of unknown origin. The shoreline slope was gradual with species in *Populus* (cottonwood and poplar), *Ulmus* (elm), *Salix* (willow), and *Quercus* (oak). Approximately 70 percent of the shoreline was used for pasture but only the northwest portion was heavily grazed.

Another survey was conducted 38 years later in 1991. The survey (MN DNR 2011) noted the following: the shoreline length was 4.8 km, 2.5 km more than in 1953, the maximum depth of the lake was 0.9 m, 0.8 m less than in 1953, and the median depth was 0.9 m, 0.3 to 0.5 m less than in 1953. The lake bottom was described as muck. Nine aquatic plant species were located in 1991 while 24 were located in 1953. All nine species located in 1991 were submergent, with eight native and one of unknown origin. Four of the submergent native species were located in both 1991 and 1953.

Terminology and Designators for Plant Classes

Plant-related terminology is extensive and very often used imprecisely. This report uses definitions for native, nonnative, exotic, translocated, naturalized, adventive, ornamental, weed, early-successional, noxious species, invasive species, forbs, grass, and indicator species as defined in "Native, Invasive, and Other Plant-Related Definitions" (USDA 2012b) and other sources as follows:

A **native** plant species has evolved in a particular region over a period of hundreds or thousands of years, without human intervention (Fernald 1950; USDA

2012b). In this study, natives are those species that were present in North America before European settlement.

Nonnative or introduced plant species occur in areas where they have not previously been located. Most nonnatives were introduced by humans intentionally or accidentally (USDA 2012b). An **exotic** plant is one that is nonnative to the continent where it is currently found growing (USDA 2012b). For example, a plant species native to China would be considered exotic in the United States. **Translocated** plant species differ from exotic plant species in that they are found in a different region of their native continent. For example, a plant species native to Florida would be considered translocated in California.

Nonnatives that persist in new locations and begin to reproduce without human assistance are said to be **naturalized**. Naturalized plant species are often found near areas of human disturbance (USDA 2012b) because they are often early-successional species, introduced accidently, or have escaped from horticultural or agricultural settings into natural areas (Curtis 1971). Some nonnative species become widely and permanently established while others only persist within specific habitats or exist temporarily because conditions are temporarily ideal for their maintenance and propagation. Such species are referred to as **adventive** (Muehlenbach 1969). Nonnative plants that cannot reproduce without human assistance and are generally found in horticultural and agricultural settings are called **ornamentals** (USDA 2012b)**.**

Ralph Waldo Emerson (1878) famously defined a **weed** as “a plant whose virtues have not yet been discovered.” Generally speaking, a weed is a plant growing in a place where it is not wanted, so therefore what constitutes a weed is highly subjective; a plant that is desirable to one person may be undesirable to another. Traditionally, weeds are defined as objectionable and undesirable plants that disrupt human activities or health (Hamill et al. 2004) or interfere with management goals and plans (Randall 1996). Many species classified as weeds by the University of Minnesota Extension (UM-Ext) (2015a, 2015b, 2015c), Minnesota Department of Agriculture (MDA) (2010, 2012), and Gleason and Cronquist (1991) are actually early-successional species such as native annual species *Conyza canadensis* (horseweed), and species in *Chenopodium* (lamb's quarters) and *Amaranthus* (pigweed). These "pioneer species" grow in open disturbed sites because of their ability to endure environmental extremes and utilize limited resources (Bazzaz 1974). As early-successional species increase in density, they change environmental conditions by decreasing soil temperature and increasing nutrient availability, which creates suitable growing conditions for mid- and late-successional species. Eventually, mid- and late-successional plant species, herbaceous perennials and shrubs in a prairie, crowd out early-successional annual species like horseweed, lamb's quarters, and pigweeds (Curtis 1971; Foster and Tilman 2000). Naturalized nonnative annuals, biennials, and short-lived perennials such as *Thlaspi arvense* (field pennycress), *Bromus commutatus* (hairy chess brome), and *Taraxacum officinale* (dandelion) serve the same function. In the context of this study, annual and other short-lived pioneer species listed as weeds by the UM-Ext (2015a, 2015b, 2015c), MDA (2010, 2012), and Gleason and Cronquist (1991) (Table G1) and are otherwise not classified as noxious or invasive, will be referred to as **early-successional species**.

A **noxious species** is any native or nonnative plant species that has been judged to injure or cause damage to agriculture, human health, or the environment (USDA 2012b; MDA 2012). Under the Minnesota Noxious Weed Law (Minnesota Statutes 18.75 to 18.91), landowners are required to control or eradicate these species (Durgan 1998). Categories include prohibited, restricted, and secondary noxious species (Minnesota Rules 1505.0730 to 1505.0750) (MDA 2010). As of this writing, the State lists 11 prohibited noxious species and two restricted noxious species (*Rhamnus cathartica* [common buckthorn] and *Frangula alnus* [glossy buckthorn]), which may not be imported, sold, or transported within Minnesota (MDA 2010). The State lists 52 secondary noxious species that may be added to a county's prohibited or restricted list as requested by the county. In Nicollet County, where the Oak Leaf Lake Unit is located, the secondary noxious species include *Xanthium pensylvanicum* (cocklebur), *Helianthus tuberosus* (Jerusalem artichoke), *H. annuus* (wild sunflower), and *Abutilon theophrasti* (velvetleaf) (MDA 2010). *Ambrosia artemisiifolia* (common ragweed) and *A. trifida* (giant ragweed) are native early-successional species that are classified as secondary noxious species because their pollen causes hay fever.

Invasive species are naturalized nonnatives that outcompete native species, spreading widely enough in an area to replace natives and disrupt entire communities (Hamil et al. 2004; Curtis 1971; USDA 2012b). Presidential Executive Order 13112 defines an invasive plant species as "a nonnative species that causes or may cause economic or environmental harm or is a threat to human health" (USDA 2012a). Not all nonnative naturalized plants are invasive; many serve as early-successional species that coexist with native species and do not disrupt community composition (USDA 2012b). Many invasive species like *Phalaris arundinacea* (reed canary grass), *Cirsium arvense* (Canada thistle), and *Arctium minus* (common burdock) are also classified as noxious species.

Ecological studies often use the term **forb** to describe annual, biennial, or perennial vascular, herbaceous flowering plants that are not "grasslike," i.e. grasses, sedges, or rushes, which are often lumped into the term **grass** (USDA 2012c). A forb lacks substantial woody tissue at or above the ground, but may have perennating buds at or below the surface of the ground (USDA 2012c).

Prairies are complex entities controlled by many interacting factors, which makes it difficult to find widely-accepted standards to measure their quality. In general, a high-quality prairie will resemble pre-settlement prairies and will resist encroachment by nonnative species. One common way to assess their quality is through the use of **indicator species** (Carlson 2010; MN DNR 2012a). The MN DNR County Biological Survey (Carlson 2010; MN DNR 2012a) includes easily-identifiable native species that are sensitive to particular environmental conditions, such as grazing, with Tier 1 species being more sensitive than Tier 2 species. Ratios of Tier 1 and Tier 2 species to non-indicator species allows investigators to rate the relative quality of a prairie because the indicators usually fill niches in stable late-succession prairies (Bartha et al. 2003; Carlson 2010; MN DNR 2012a). Curtis (1971) also lists indicator species that reach their peak growth within narrow ranges of conditions signaling high quality communities.

Floras and Floristic Surveys

A **flora** is a list of all naturally-occurring native and naturalized nonnative plant *species* found within an area of interest (A. Mahoney, personal communication, June 15, 2015). Agricultural and horticultural species in fields and gardens are not included unless they have naturalized.

A floristic survey generates a flora by listing all plant species in a specific area and is used to determine the number (species richness), distribution, and relationships of the taxa present. Floristic surveys are usually carried out by thoroughly walking through a site periodically during the growing season with the goal of identifying all species present (Carter et al. 2007). It is customary to collect and preserve a **voucher specimen** for each species encountered (Goldblatt et al. 1992). Voucher specimens are pressed, dried plants or pieces of plants mounted on heavy paper stock with labels indicating where and when they were collected and by whom (Goldblatt et al. 1992). Vouchers are stored in herbaria and are critical to scientific studies because they are used to verify the correct identity and presence of species used in the studies (Goldblatt et al. 1992). In addition to basic collection information, voucher labels may provide ecological data and notes on habitat, such as associated plant species, flowering date, soil type and moisture, and abundance. Vouchers can be used to document current and past distributions, migrations, the introduction or extirpation of species, and hybridization events (Funk et al. 2005; Carter et al. 2007). Depending on time and budget constraints, the frequency of walk-throughs can vary from study to study.

Floristic surveys allow us to track changes in floras over time because the current flora of an area holds clues to the past. Historic events, such as glaciations, have shaped soil types, available water capacity, soil pH, and topography, which control the present flora's ability to survive (Nichols 1930; Carpenter 1940; Curtis 1955; Dix and Butler 1960). Extended temperature regimes, precipitation patterns, and land-use by humans are reflected in a flora (Carpenter 1940; Stohlgren 2007; Schiebout et al. 2008).

From 1975 to 1994, a total of 603 new plant species were discovered in North America, composing 3.2 percent of the total estimated plant species in North America (Ertter 2000). Floristic surveys have discovered rare plant species previously thought to be extinct. *Trimorpha acris* var. *asteroids* (bitter fleabane) was rediscovered in 2000 in the Boundary Waters Canoe Area in Minnesota after not being reported for 55 years. *Carex rossii* (Ross's sedge) was rediscovered in 1999 in Cook County, Minnesota after not being reported for more than 100 years (MN DNR 2012a). Floristic surveys also identify nonnative or invasive species that can be health or economic threats (Schiebout et al. 2008). For example, *Pastinaca sativa* (wild parsnip) was first identified in Ramsey County, Minnesota in June 2015 (UGCISEH 2015). Wild parsnip causes phytophotodermatitis, in which skin exposed to the sun after coming in contact with the plant sap develops a rash and painful blistering (USDA 2012c).

Floristic surveys also identify changes in plant distributions. In 1999, *Disporum trachycarpum* (rough-fruited fairy bells) was found for the first time in Minnesota (MN DNR 2012a). It had previously only been found in the northwestern and western United States and Canada, with the closest populations to Minnesota in North Dakota, Michigan, and Ontario. These data are valuable in tracking the effects of global climate change on plant species abundance and distribution (Schiebout et al. 2008); some rare plant species may flourish and become more abundant, while other common species may become rare (Bezemer and Jones 1998; Primack 2006).

Floristic surveys bring attention to habitat heterogeneity. Floristic surveys help to delimit and measure ecotones and gradients (moisture, elevation, pH, aspect, etc.) that define them. They locate rare species, which are often confined to specialized habitats, fill unique ecological niches, i.e. by forming mutualistic relationships with other organisms, etc. Rare plant species are integral to biodiversity and can be used as indicator species to assess the ecological quality of an area (Stohlgren 2007). Studies show that a community with high biodiversity is more resilient, more stable, more able to withstand and adapt to changes, and improves and maintains soil health (Stohlgren 2007).

Vegetation and Vegetation Surveys

Vegetation is defined as the *kind* of plants growing within a region. Earth's biomes are defined by their vegetation (Simpson et al. 2007), i.e., high-light-tolerating grasses and forbs occur on prairies, while trees, shrubs, and low-light-tolerating herbaceous species occur in a deciduous forest. Because the kind of vegetation an area supports is the result of climate, soils, water availability, topography, and other factors, vegetation data are useful in studies of evolutionary adaptations of species and the assessment of environmental conditions (Craig et al. 2007; Simpson et al. 2007). Vegetation surveys are often performed to assess habitat quality for fauna of interest.

Vegetation studies delineate areas based on dominant plant species or types of species, which precludes fine-scale community analysis (Stohlgren 2007). Vegetation studies are generally undertaken on relatively large areas; they usually rely on data taken from randomly-located transects divided into smaller quadrats (Sparks et al. 1997). If an area is made up of more than one vegetation type, distinguishing between the two can be difficult. Often the area is subdivided into more than one area by vegetation type. Rather than providing a list of plant species, vegetation surveys provide an "ecological snapshot" of an area, describing its overall characteristics. Vegetation surveys provide quantitative data such as number of plant species found in a quadrat, percent cover of each class of plant, and litter depth (Sparks et al. 1997). Quantitative data allow statistical analyses, which floristic data are usually unable to provide. Depending on the data collected and the results desired, the time spent on data collection and analysis can be comparable to that of a floristic survey. However, because data are usually confined to transects, species that do not occur in the transects will be omitted from analyses.

Physiological Requirements of Plants

Species are adapted to the climates (length of growing season, annual precipitation, and temperature patterns) of their geographic ranges (Raven et al. 2005; Solomon et al. 2005; Brooker et al. 2008). For instance, many desert plants have developed photosynthetic stems that can store water; their leaves have evolved into spines, which not only deter herbivores but help break up desiccating wind currents that strike the plant's surface (Raven et al. 2005). Despite an extraordinary ability to endure prolonged drought, some spine succulents are very sensitive to freezing temperatures. The giant saguaro cactus (*Carnegiea gigantea*) survives overnight frosts, but if temperatures remain below freezing for more than 36 hours, individuals will die (Brooker et al. 2008). Earth's biomes are defined by the kinds of plants that survive within the climatic parameters of the region (Raven et al. 2005; Solomon et al. 2005; Brooker et al. 2008). Prairie species are adapted to relatively low annual precipitation, cold winters, and warm to hot summers.

Species also differ in their ability to thrive in dry to wet substrates and are categorized based on their ability to survive in varying soil moisture regimes. Knowing species' soil moisture requirements and their distributions can provide information about habitat conditions on a site. The United States Army Corps of Engineers Region 3 Midwest 2014 Wetland Plant List (Lichvar et al. 2014) classifies species according to their soil moisture requirements. For species not included in the Army Corps' list, I adapted Ladd's (2005) coefficients of wetness, which lists values ranging from -5 (prefers wet soils) to 5 (prefers dry soils) for 988 prairie species. The combined moisture categorizations used in this study are defined as follows : obligate wetland (OBL = -5, almost always found in wetlands), facultative wetland (FACW = -1 to -4, usually found in wetlands, but may occur in non-wetlands), facultative (FAC = 0, found in wetlands and non-wetlands), facultative upland (FACU = 1 to 4, usually found in non-wetlands, but occur in wetlands), and obligate upland (UPL = 5, almost never found in wetlands) (Ladd 2005; Lichvar et al. 2014). Facultative species cope well with a variety of moisture levels. Obligate species are limited to a narrower range of conditions.

Succession

Succession is the gradual process of change in vegetation in an area over time (Primack 2006). Primary succession occurs at sites where a new substrate has been exposed and no soil or life forms are present (Walker and Del Moral 2003; Solomon et al. 2005; Brooker et al. 2008). A retreating glacier and lava flow are two common causes of new substrate formation (Encyclopaedia Britannica 2012). Lichens are usually the first species to colonize new substrates (Raven et al. 2005; Solomon et al. 2005; Brooker et al. 2008). These pioneer species begin to break down bare rock and contribute their organic matter to produce the soils required by plants. Except in the most inhospitable habitats, plants will become established, eventually crowding out the pioneer species.

Secondary succession involves a disturbance that destroys the community, but not the soil or nutrients. Secondary succession occurs after fires, floods, hurricanes, and tornadoes (Solomon et al. 2005). It also occurs on roadsides, vacant lots, construction sites, abandoned agricultural crop fields, and abandoned logging operations in old-growth forests (Solomon et al. 2005). Under these conditions, herbaceous annual plants are generally the pioneer species (Solomon et al. 2005). They are tolerant of high levels of sunlight, high temperatures, and low water availability; they generally produce many seeds (or spores if they are seedless vascular plants) that migrate to an area quickly via wind (Brewer 1994; Primack 2006). In fact, many of our "weeds" are pioneer species. Disturbed areas, such as ant and animal mounds, are often rapidly occupied by early-successional nonnative species such as *Melilotus alba* (white sweet clover), *M. officinalis* (yellow sweet clover), and *Elytrigia repens* (quackgrass), as well as native early-successional species such as *Ambrosia artemisiifolia* (common ragweed), *A. trifida* (giant ragweed), *Conyza canadensis* (horseweed), and *Erigeron strigosus* (rough fleabane) (Curtis 1971). They alter the habitat by shading the soil surface, which keeps it cooler and reduces evaporation, increasing soil organic matter, and reducing erosion. In a temperate zone like Minnesota, they pave the way for mid-successional prairie species, such as herbaceous perennials *Verbena stricta* (hoary vervain), *Rudbeckia hirta* (black-eyed Susan), *Ratibida pinnata* (gray-headed coneflower), and *Monarda fistulosa* (wild bergamot), that require more shade and moisture to become established (Curtis 1971; Kline 2005). Only the most mature prairies support "conservative species" such as *Silphium laciniatum* (compass plant), *Veronicastrum virginicum* (Culver's root), *Symphyotrichum oolentangiense* (prairie heart-leaved aster), and many legumes (Kline 2005). In addition to spreading by seeds, perennial species often spread vegetatively using perennating organs such as rhizomes, creeping roots, or other means. They gradually replace pioneer annual species by shading and crowding them out (Whitefield 2002). In south-central Minnesota, fast-growing, shade-intolerant woody species such as willow and cottonwood germinate among herbaceous perennials (Grimm 1983). Seedlings of shade-tolerant woody species such as some *Quercus* (oak) and *Acer* (maple) species and *Tilia americana* (American basswood) germinate in the understory. As these trees mature, they gradually replace willows, poplars, and high-light-requiring herbaceous perennials. They, in turn, provide appropriate conditions for low-light-adapted understory species. Once the plant community of an area has stabilized and can withstand disturbances, it is said succession has reached its climax (Dice 1962; Tester

1995; Brooker et al. 2008; Encyclopaedia Britannica 2012). In south-central Minnesota, maple-basswood associations are common climax communities. Climax vegetation differs considerably from place to place depending on climate, latitude, and small-scale features such as elevation and aspect, pH, soil type and moisture, etc. (Raven et al. 2005). Although considered stable, a region's vegetation and/or flora is not static (Raven et al. 2005) and its composition may continue to change in response to changing environmental conditions.

Data Collection Methods: Walk-Through and Random-Sampling-in-Quadrats

The Walk-Through Method

The walk-through method collects floristic data by thoroughly walking through a study site on several occasions during a growing season. All plant species found are identified; voucher specimens are collected or, if species are rare or endangered, a photograph serves as a voucher. Generating the flora is an additive process. Once a species is on the list and a voucher preserved, it is usually not noted again on subsequent visits. The goal of this method is to find and list every plant species on the site.

The Random-Sampling-in-Quadrats Method

Data collection via the random-sampling-in-quadrats method (referred hereafter as the "random-sampling method") is carried out in experimental plots or in an area of interest, sometimes within randomly-located units called transects. A transect is a line laid out within the study area and data collection points occur either randomly or at regular intervals along the line. Data collection (sampling) is also carried out within smaller units within areas called quadrats. Many experiments utilizing quadrats use a constructed frame that is easily transportable from data point to data point to clearly define the quadrat boundaries and to ensure uniformity of quadrat sampling area throughout the experiment. Sampling using quadrats can be done with or without a transect line.

Random sampling requires both spatial and temporal considerations. The spatial aspect of the random-sampling method involves choosing the appropriate quadrat size and shape and ensuring a sufficient number of samples have been taken. The best quadrat shape is dictated by the study site. A very commonly-used quadrat size for sampling herbaceous plant species is the standard rectangular 20 cm by 50 cm Daubenmire frame; however, a Daubenmire frame is impractical in a deciduous forest setting. Quadrat sizes have costs associated with them, as pointed out by Stohlgren's (2007) case study, which determined that approximately 30 percent more species were located when a quadrat was tripled in size, but required much more time to sample. Stohlgren (2007) found that a 1 m^2 quadrat was more cost-effective than either a 0.34 m^2 quadrat or a 3 m^2 quadrat. One m^2 quadrats yielded significantly greater numbers of different plant species (indicating species richness) than 0.1 m^2 quadrats (the same area as a Daubenmire frame) (Barnett and Stohlgren 2003; Stohlgren 2007), indicating that smaller quadrat sizes can underestimate species richness by missing rare species. Keeley and Fotheringham (2005) compared square and rectangular quadrats and found no significant difference in species richness within the same vegetation type. Keeley and Fotheringham (2005) also determined only one significant difference when comparing square and rectangular quadrats in pairwise comparisons among different vegetation types. In this comparison a square quadrat yielded significantly greater species richness. Randomly-placed quadrats capture plant patchiness and are therefore better at analyzing heterogeneous areas than linearly- or uniformly-placed quadrats (Stohlgren 2007). The linear or uniform placement of quadrats, tends to oversample common habitats within the study area and can completely miss a rare/small habitat (Stohlgren 2007), thus greatly underestimating species richness. From the preceding data, I concluded that randomly-sited, 1 m^2 square-shaped quadrats would provide the most cost-effective and efficient model for my study site because it theoretically would yield a greater cumulative number of plant species, be less likely to miss rare species, and could be carried out within the shortest period of time.

To determine if "all" species in an area have been counted (sampled), a species area curve is calculated: the cumulative number of species located is plotted against the cumulative sample size (m^2). Sampling is considered sufficient when the plot line reaches a plateau (Schiebout et al. 2008).

The temporal aspect of the random sampling method involves the frequency of sampling. Most agencies have limited resources (money, time, people) and opt to visit a site once during the growing season. Because flowering plants are usually identified using floral characters, immature plants may evade inclusion or be identified incorrectly

(A. Mahoney, personal communication, June 15, 2015). More than one sampling event during the growing season is preferred to best identify all plant species present on a site.

Data Collection and Analysis

Several kinds of data are collected during walk-through and random-sampling assays. These data can be used to calculate various indices.

Data Collected and Indices Calculated

Species richness is the number of species located within a specified area (Whittaker 1972). **Species abundance** is usually an estimate of the number of individuals of each species present (Whittaker 1972). **Species diversity** is an index that combines the number of species and abundance evenness (whether species are found throughout an area or if their occurrences are patchy) (Whittaker 1972). As both species richness and abundance are required to calculate species diversity, only data collected by the random-sampling method can be used to generate this index.

One measure of species diversity is the **Shannon-Wiener Index** (*H*), which is calculated as follows:

$$H = \sum P_i \ln P_i$$

where P_i is the proportion of individuals of species *i* within the sample (Bazzaz 1975). The greater the *H* value, the greater the species diversity (Bazzaz 1975; Stohlgren 2007; Gibbs et al. 2008), meaning that as *H* increases, so does the species richness and evenness. *H* usually ranges between 1.5 and 3.5 and rarely exceeds 4.0 (Magurran 2004).

Values greater than 4.0 are usually only produced when data come from very large samples; Magurran (2004) states calculating an *H* value greater than 5.0 would require a sample size of 10^5 units. This study uses the Shannon-Wiener Index to determine species diversity from data collected by the random-sampling method.

The **Simpson's Index of Diversity** (*D*), another index of species diversity, is calculated as follows:

$$D = 1 - \sum p_i^2$$

where p_i is the proportional abundance of the *i*th species. *D* ranges from zero to one. The greater the *D* value, the greater the diversity (Gibbs et al. 2008). The Simpson's index places more weight on species abundance than on species richness (Magurran 2004). This study uses the Simpson's Index of Diversity to determine species diversity from data collected by the random-sampling method.

Jaccard's (1908) **coefficient** (C_j) is used to assess the similarity between members of two data sets. Jaccard's (1908) coefficient is calculated as follows:

$$C_j = \frac{a}{(a+b+c)}$$

where *a* is the number of entities shared by both sets and *b* and *c* are the number of entities unique to each data set, respectively (Rice and Belland 1982). The values for C_j range from zero to one. A greater C_j value indicates greater similarity between the sets, so a C_j value of zero means the two sets have no entities in common and a C_j value of one means the two sets share all entities (Rice and Belland 1982). This study uses Jaccard's coefficients to compare similarities between the number of species located using the walk-through method and the random-sampling method at the study site. Data from the study site were also compared with data from other prairie locations in Minnesota.

Frequency is a measure of the uniformity of the distribution of a plant species in an area (Daubenmire 1968). Frequency is calculated as follows:

$$f_i = j_i/k$$

where f_i is the frequency of a species, j_i is the number of quadrats containing species i, and k is the total number of quadrats sampled. In the case of random-sampling, frequency does not specifically track how many individual plant species exists within each quadrat; instead it tracks the species' presence or absence (Daubenmire 1968).

Percent cover is the ranked percentage of ground surface within a specified area (e.g. a quadrat) that is covered by an entity (= category), such as type of vegetation or bare ground, or rocks (Daubenmire 1959). For each of the six cover classes (1 = 0-5%, 2 = 5-25%, 3 = 25-50%, 4 = 50-75%, 5 = 75-95%, and 6 = 95-100%) within each of the seven cover categories (native grass, nonnative grass, native forb, nonnative forb, duff/litter, bare ground, and other (rocks, moss, etc.); percent cover was calculated as follows:

$$\text{Percent cover} = \frac{(\text{number of quadrats containing the cover class})*(\text{midpoint of the cover class})}{\text{Total number of quadrats sampled}}$$

Species area curves are used to determine when a sufficient number of samples have been collected by charting the number of species found against the cumulative area of the study site. When the curve plateaus, an adequate area has been sampled and additional sampling would yield little or no additional species (Schiebout et al. 2008). Area (m^2) is plotted on the x-axis and Mean Plant Species Richness is plotted on the y-axis.

The Wilhelm Floristic Assessment Method (Swink and Wilhelm 1994) assigns a **Coefficient of Conservatism**, or C-value, to each native species. C-values are based on their "conservatism," or ability to tolerate disturbances, and the likelihood that a species will be found in remnant natural (undisturbed) habitats. They range from 0 to 10 with 10 being the most conservative and hence, the most sensitive indicators of a high-quality prairie (Higgins et al. 2001; TNGPFQAP 2001). For instance, *Veronicastrum virginicum* (Culver's root) and *Aster oolentangiense* (prairie heart-leaved aster) are assigned C-values of 10 because they are more intolerant of disturbances and therefore are rarely found outside high-quality sites. Species within the mid-range of C-values, such as *Verbena hastata* (common or blue vervain) or *Heliopsis helianthoides* (common oxeye), both with C-values of 5, are species that can be found in high quality sites as well as disturbed sites (Higgins et al. 2001) because they have more tolerance to disturbance than species of higher C-values (TNGPFQAP 2001). Species with C-values of 0 are often found in disturbed areas and are native early-successional species, such as *Ambrosia artemisiifolia (*common ragweed) or *Conyza canadensis* (horseweed) (Higgins et al. 2001; TNGPFQAP 2001). Nonnative species are not given C-values.

Swink and Wilhelm (1994) developed their C-values for the Chicago region. The Northern Great Plains Floristic Quality Assessment Panel (TNGPFQAP 2001) expanded the system to include North and South Dakota and adjacent grasslands. Minnesota has not yet developed C-values for its prairie flora. I used the TNGPFQAP (2001) C-values for my calculations because the flora at my site is similar. When TNGPFQAP values for species at the site were unavailable, I substituted values listed in Ladd (2005). C-values are used to calculate a mean C-value, which can be used to assess the quality of a site. Mean-C ($\overline{C}$) is calculated as:

$$\overline{C} = (\sum C)/N$$

where the sum of the C-values (C) for all species at a site is divided by the total number of species at the site (N).

To further gage the quality of a site, a **floristic quality index** (FQI) can be calculated using mean-C. Mean-C simply summarizes the overall floristic ranking; the FQI provides a weighted species-richness factor that provides a better measure of prairie quality (Higgins et al. 2001; TNGPFQAP 2001). Areas with a FQI of 35 or below are considered to have an insufficient number of native species and inadequate biodiversity, FQIs close to 45 are representative of fairly decent quality areas but have some deficiencies in biodiversity, and FQIs close to 60 are found at the most diverse locations (Swink and Wilhelm 1994; Higgins et al. 2001). FQI is calculated as:

$$FQI = \overline{C}\sqrt{N}$$

where $\overline{C}$ is the mean C-value and N is the total number of species at the site.

Two sites may have similar mean-Cs but very different FQIs, or vice versa, if they have large differences in the number of native species at each site (TNGPFQAP 2001).

FQI scores can be used to compare plant distributions and ecological changes at a site over time (Schiebout et al. 2008).

Table H1 summarizes indices used in this analysis.

Statistical Analyses

One-way analysis of variance (ANOVA) tests whether two means are statistically significantly different (Hawkins 2009). I used ANOVA to compare mean daily temperature per month and mean daily precipitation per month during the two seven-month growing seasons (April through October) in 2011 and 2012 with the 30-year mean for 1981 to 2010.

Because growing season lengths for 2011 and 2012 are not means, ANOVA cannot be used to calculate statistical differences. The 95 percent confidence interval for the 30-year mean growing season length in days was calculated to determine if the growing season length in days for 2011 and 2012 were within the confidence interval.

Taxonomy

Taxonomy is a discipline within Systematics that identifies and classifies organisms in a hierarchical system. Our current system contains the following levels or taxa (listed from most- to least-inclusive): domain, kingdom, phylum, class, order, family, genus, and species. Species may be further classified into subspecies or varieties. Organisms within one group are assumed to be more closely related to each other than to organisms in a different group within the same taxon. For example, species within a genus are more closely related to each other than to species in other genera. Historically, classification was determined by morphological characters; greater physical or physiological similarity was assumed to indicate closer evolutionary relationships (Primack 2006). Today, taxonomists are revising older systems based on evidence from molecular analyses (Primack 2006).

Every species has a unique scientific name or "binomial" made up of two Latin names: the first, the generic name, represents the genus to which the organism belongs and the second name, the specific epithet, represents the species within the genus to which the organism belongs. The author of the plant name follows the specific epithet, thus completing the name. This system was developed in the 18^{th} century by Swedish botanist, Carolus Linnaeus, often touted as the "Father of Taxonomy." Prior to the 1753 publication of Linnaeus's *Species Plantarum*, scientific names consisted of cumbersome descriptive phrases and then, as now, common names were often inconsistent from region to region (Primack 2006). Binomial nomenclature has been adopted as the international standard for naming organisms.

OBJECTIVES

The primary objective of this study was to perform a floristic survey of a portion of the Oak Leaf Lake Unit of the Swan Lake Wildlife Management Area in Nicollet County, Minnesota to provide baseline data for future research and to assess the ecological quality of the site by calculating species richness and FQI and using Jaccard's indices to compare its flora to that of other prairies in the region. The secondary objective was to compare the effectiveness of walk-through and random-sampling-in-quadrats methods in providing floristic data.

HYPOTHESES

My first null hypothesis is that species richness and FQI for the study site will not differ from the species richness and FQI of other prairies in the region. My alternative hypothesis is the study site will have lower species richness and FQI than other prairies in the region.

My second null hypothesis is that species richness, as determined by the walk-through method, will not differ from species richness as determined by the random-sampling-in-quadrats method. My alternative hypothesis is the walk-through sampling method is more likely to generate greater species richness than the random-sampling-in-quadrats method.

METHODS

Precipitation and Temperature Data for 2011 and 2012

I obtained mean daily temperature and daily precipitation records from the Midwestern Regional Climate Center (MRCC) (2014), a cooperative program of the Illinois State Water Survey and the National Climate Data Center, at their Saint Peter, Minnesota location (latitude 44.3222, longitude -93.9656, approximately 4 km east of the Oak Leaf Lake Unit). I used ANOVA to test whether mean daily precipitation per month and mean daily temperature per month over the seven-month growing seasons (April through October) in 2011 and 2012 differed from the monthly means for the 30-year period from 1981 to 2010. Because growing season lengths for 2011 and 2012 are not means, the 95 percent confidence interval for the 30-year mean growing season length in days was calculated to determine if the growing season length in days for 2011 and 2012 could be considered typical.

Tools such as the Palmer Hydrological Drought Index (PHDI) measure long-term cumulative (usually 12 months) drought and wet conditions to more accurately reflect the long-term consequences of drought, such as its effect on groundwater and reservoir levels (NOAA 2014) and prairie flora. Table 1 gives PHDI values, ranging from -4.00 and below to +4.00 and above, and corresponding hydrologic conditions.

Table 1. Range description and corresponding range values for measuring long-term cumulative drought and wet conditions according to the Palmer Hydrological Drought Index (NOAA 2014).

Range Description	Range Values
extremely moist	+4.00 and above
very moist	+3.00 to +3.99
moderately moist	+2.00 to +2.99
mid-range	-1.99 to +1.99
moderate drought	-2.00 to -2.99
severe drought	-3.00 to -3.99
extreme drought	-4.00 and below

Monthly PHDI values reported for the 2011 and 2012 growing seasons were also gathered and used in my analysis.

Floristic Survey 2011

The walk-through method was used to conduct a floristic survey of the Oak Leaf Lake Unit in 2011. The area was thoroughly walked through 13 times (at least once every two weeks) between June 13 and September 23. Data collected within three time periods were designated as “early-” (**I** = June 3 – July 6), “mid-” (**II** = July 7 – August 13), and “late-blooming/fruiting” (**III** = August 14 – September 23), respectively, for comparison with random sampling events carried out in 2012 (Table D1). Voucher specimens were made for species in bloom when sufficient numbers of individuals were present. In cases where very few individuals of a species were found, specimens were not collected; notes and photographs provide evidence the species was present. Voucher specimens were prepared according to recommendations of the Radichel Herbarium at Minnesota State University, Mankato (MANK) and also housed there (MANK 2012). Species were identified using the *Manual of the Vascular Plants of Northeastern United States and Adjacent Canada, Second Edition* by Henry A. Gleason and Arthur Cronquist (1991) and the *Illustrated Companion to Gleason and Cronquist's Manual of the Vascular Plants of Northeastern United States and Adjacent Canada: Illustrations of the Vascular Plants of Northeastern United States and Adjacent Canada* edited by Noel H. Holmgren et al. (1998). Other sources were helpful in species identification, such as the USDA PLANTS Database (USDA 2012c). A list was compiled of all species collected/observed including family, genus and species name, author, common name, native or nonnative status, collection number, site section of the plant location within the site, date collected/observed, whether the species was also located in 2012, the blooming/fruiting period (I, II, III) in which the species was collected, growth habit, duration (annual, biennial, or perennial), the time and length of the typical bloom period/fruiting season of the species, habitat, wetland code, C-value, indicator species status, invasive species status, noxious species status, and if the species was also located at Kasota Prairie (Tables D1, E1).

To facilitate providing ecological data for voucher specimen labels, the site was divided into three roughly-equal-sized areas based on soil type and other habitat characteristics (Figure B1). Note that the site was treated as a whole for sampling purposes and was not split up into sections when the walk-through and random-sampling methods were deployed. Section A, on the western side of the site, was at the highest elevation and had the driest soils. It included many disturbed areas, including the driveway, parking area, and boat access. Section B was located in the middle of the site and was predominantly grassland. It slopes downhill from west to east and its soils change from predominantly Cordova clay loam to Cordova-Rolfe complex and Klossner-Muskego soils ponded, resulting in greater available water capacity and frequency of ponding towards the east side. Section C, located at the east side of the site, contained wetlands and also had greater available water capacity and frequency of ponding.

Random Sampling 2012

Random sampling was conducted three times during the 2012 growing season on June 3 (designated **I**, early-blooming/fruiting), July 21 (designated **II**, mid-blooming/fruiting) and September 9 (designated **III**, late-blooming/fruiting) (Table D1).

To create a compatible floristic data set so that the floras generated in 2011 and 2012 could be compared, each species was counted once and assigned to the blooming class (I, II, or III) in which it was first encountered (see page 37 for date range for each blooming class). Seventy-five randomly-located 1 m^2 square-shaped quadrats were sampled on each of the three dates for a total of 225 quadrats. Species area curves were generated to ensure an adequate number of random points had been sampled (Figures F1, F2, and F3). Random points were generated using Geographic Information System software by Environmental Systems Research Institute (ESRI 2011). A hand-held Global Positioning System unit was used to locate the random points in the field, where a 1 m^2 frame was placed with its lower right-hand corner positioned on the random point thus forming the southwest corner of the quadrat. All plant species growing within the quadrat were identified and recorded and a list was compiled including family, genus and species name, author, common name, native or nonnative status, collection number, site section of the plant location within the site, date collected/observed, the blooming/fruiting period (I, II, III) in which the species was collected, growth habit, duration (annual, biennial, or perennial), the time and length of the typical bloom period/fruiting season of the species, habitat, wetland code, C-value, indicator species status, invasive species status, noxious species status, and if the species was also located at Kasota Prairie (Tables D1, E1).

Entities within each quadrat were classified in the following categories: native grass, nonnative grass, native forb, nonnative forb, duff/litter, bare ground, and other (rocks, moss, etc.). The categories' areas were measured so that percent cover for each category could be calculated (Daubenmire 1959, 1968) and assigned a "Cover Class"

(Table 2). Species frequency and richness were also calculated for each category as applicable.

Table 2. Cover classes and corresponding percent cover (Daubenmire 1959, 1968). The percentages of each cover category (native grass, nonnative grass, native forb, nonnative forb, duff/litter, bare ground, and other [rocks, moss, etc.]) within a 1 m^2 quadrat were assigned a corresponding cover class.

Cover Class	Percent Cover
1	0 - 5%
2	5 - 25%
3	25 - 50%
4	50 - 75%
5	75 - 95%
6	95 - 100%

The number of species in 2011 located in each growing season time period was compared to the number of species in 2012 located for the **first time** in each growing season time period. The walk-through method only sought out new species during each site visit and did not document species if they had previously been located, while the random-sampling method collected data on all species during each site visit whether or not they were located in previous site visits. Early spring (April through June 2) was considered part of Period I of the growing season even though the site was not visited during those dates in either 2011 or 2012.

The data gathered from each sampling technique were compared and used to calculate indices to determine similarities and differences in species identified, species richness, percent native and nonnative, and percent rare or endangered. The mean coefficient of conservatism (mean-C or $\overline{C}$) and floristic quality index (FQI) were calculated and used to compare the quality of the Oak Leaf Lake site to 11 prairies in the region. I compared the efficacy of the walk-through and random-sampling methods in their abilities to provide floristic data (as species richness) two ways: (1) by paired collection periods, I, II, and III (early-, mid-, and late-blooming/fruiting, respectively), and (2) by comparing the cumulative species richness generated by each method. This allowed me to assess which collection time, if any, provided the best "snapshot" of a site's species richness and diversity if only one visit per season could be performed.

RESULTS[1]

Precipitation and Temperature Data for 2011 and 2012

The seven-month growing seasons of 2011 and 2012 (April through October) each received less total precipitation than the 1981-2010 mean for those months (Table 3) (MRCC 2014), with 2011 receiving 12.0 cm less, or 81 percent, of the 1981-2010 mean and 2012 receiving 16.8 cm less, or 74 percent, of the 1981-2010 mean.

Figure 2 reports results of an ANOVA comparing mean daily precipitation per month for the 30-year period from 1981-2010 to the mean daily precipitation per month for the 2011 and 2012 growing seasons. Mean daily precipitation in August, September, and October 2011 were highly significantly different than the 30-year means for those

[1] Genera and species common names are given throughout the Results and Discussion Sections. Scientific names appear in Table D1.

Table 3. Mean monthly precipitation in cm for the seven-month growing season (mean last frost in April and mean first frost in October) for a 30-year period (1981-2010) and monthly precipitation in 2011 and 2012 recorded 4 km from the Oak Leaf Lake Unit (MRCC 2014). (Original data reported in inches.)

Month	1981–2010 Mean	2011	2012
April	7.4	6.4	8.5
May	8.8	12.4	21.4
June	12.3	16.5	3.4
July	10.9	12.3	6.0
August	10.7	2.6	4.0
September	7.4	0.8	1.2
October	6.3	0.8	2.5
Total	**63.8**	**51.8**	**47.0**

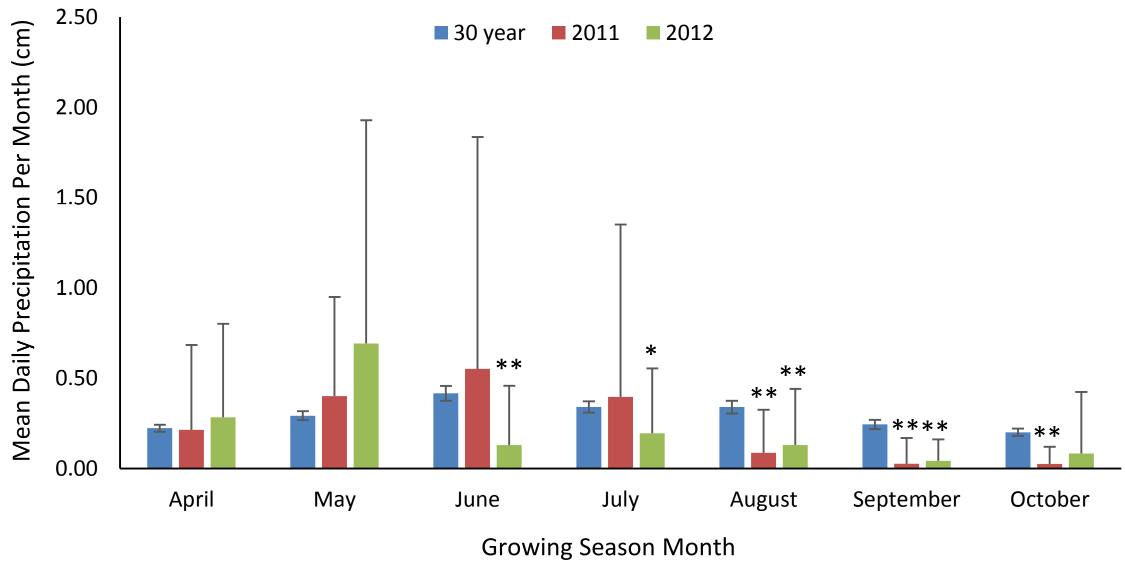

Figure 2. Mean daily precipitation per month in cm per growing season month for a 30-year period (1981-2010), 2011, and 2012 recorded 4 km from the Oak Leaf Lake Unit (MRCC 2014). Error bars show standard deviation from the means. * and ** indicate significant differences from the 30-year mean at p < 0.05 and p < 0.01, respectively.

months ($p < 0.01$). In 2012, July's mean daily precipitation was significantly different ($p < 0.05$) and means for June, August, and September 2012 were highly significantly different ($p < 0.01$) from the 30-year means for those months (Table 3, Figure 2).

The MRCC (2014) reported the growing season of 2011 overall was 0.1 °C cooler than the 1981-2010 mean and 2012 overall was 0.3 °C warmer than the 1981-2010 mean. Table 4 reports mean monthly temperatures for the 30-year period and mean monthly temperatures for 2011 and 2012 and the seven-month means.

Table 4. Mean monthly temperatures in degrees Celsius for the seven-month growing season (mean last frost in April and mean first frost in October) for a 30-year period (1981-2010) and mean monthly temperatures in 2011 and 2012 recorded 4 km from the Oak Leaf Lake Unit (MRCC 2014). (Original data reported in degrees Fahrenheit.)

Month	1981–2010 Mean	2011	2012
April	7.9	6.5	9.1
May	14.9	13.8	16.7
June	20.4	20.0	20.8
July	22.9	24.7	25.6
August	21.7	21.2	20.6
September	16.4	15.3	15.1
October	9.2	11.1	7.5
7 Month Mean	16.2	16.1	16.5

Figure 3 reports results of an ANOVA comparing mean daily temperatures per month for the 30-year period from 1981-2010 to the mean daily temperatures per month for the 2011 and 2012 growing seasons. The mean daily temperature in July 2011 was highly significantly different than the 30-year mean for that month ($p < 0.01$). In 2012, the mean daily precipitation for May and October were significantly different ($p < 0.05$)

and the mean for July 2012 was highly significantly different (p < 0.01) from the 30-year means for those months (Table 4, Figure 3).

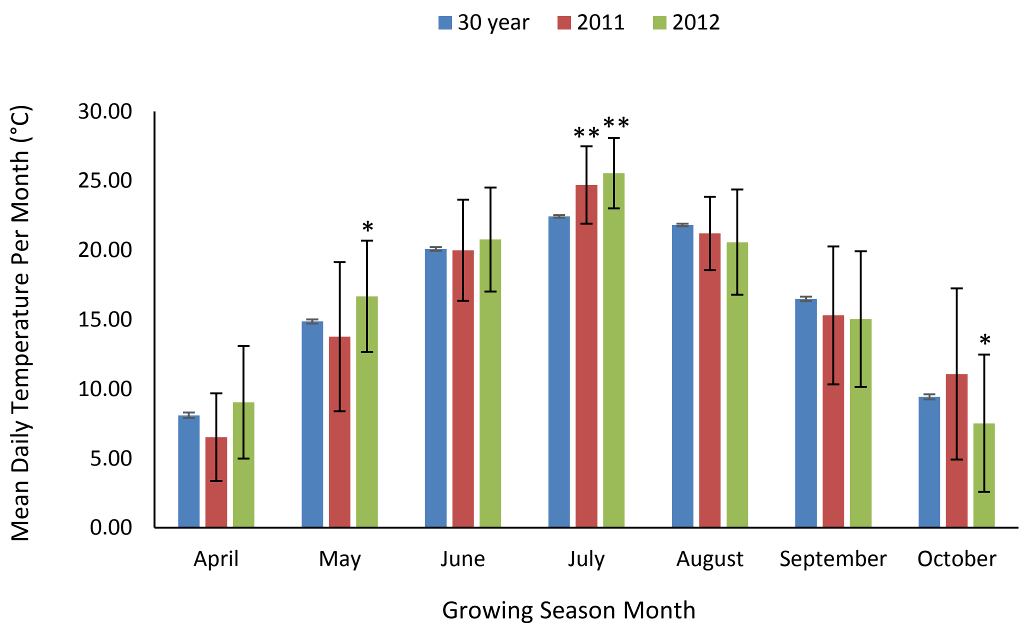

Figure 3. Mean daily temperatures per month in degrees Celsius per growing season for a 30-year period (1981-2010), 2011, and 2012 recorded 4 km from the Oak Leaf Lake Unit (MRCC 2014). Error bars show standard deviations for the means. * and ** indicate significant differences from the 30-year mean at $p < 0.05$ and $p < 0.01$, respectively.

The monthly PHDI values reported by NOAA (2014) during the growing season of 2011 ranged from -2.51 (moderate drought) to 5.02 (extremely moist) and 2012 ranged from -4.20 (extreme drought) to -1.58 (mid range) (Figure 4).

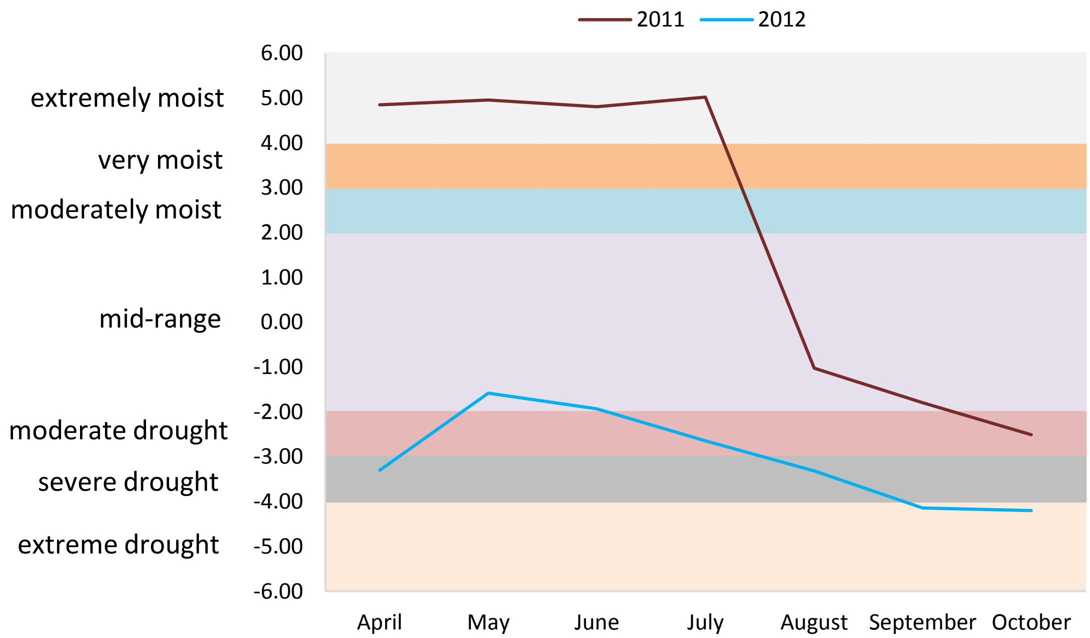

Figure 4. Monthly Palmer Hydrological Drought Index (PHDI) values for the growing seasons of 2011 and 2012. PHDI values range from -4.00 and below (extreme drought) to +4.00 and above (extremely moist) (NOAA 2014).

Differences in growing season length in days for 2011 and 2012 cannot be tested against the 30-year mean using ANOVA. I calculated the 95 percent confidence interval surrounding the 30-year sample mean (155 days ±4.79) using data from MRCC (2014). Based on this 30-year period, we expect the "true" 30-year mean to fall between 150.21 and 159.79 days during any given year 95 percent of the time. While 2012's growing season of 152 days (April 24 - September 23) (MRCC 2014) fell within the confidence interval and should be considered "typical," 2011's growing season of 134 days (May 4 - September 15) (MRCC 2014), fell well below the expected range for mean growing season length (Figure 5). Only 1 year within the 30-year period had fewer days in its growing season than 2011: 2000 with 132 days.

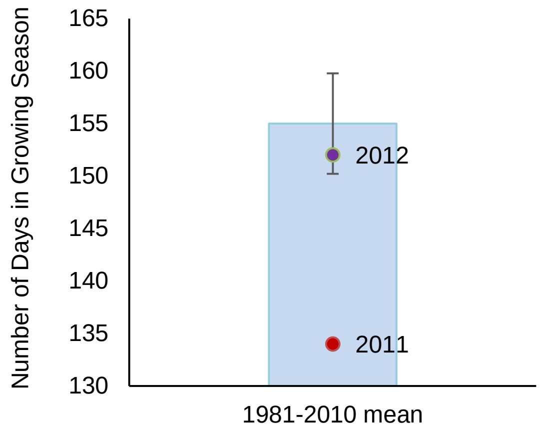

Figure 5. Mean number of days in the growing season (April-October) for a 30-year period (1981-2010) shown by bar, error bar represents the 95% confidence interval surrounding the mean. Dots represent the number of days in the growing seasons of 2011 and 2012 (MRCC 2014).

2011 Walk-Through Method

The 2011 floristic survey utilizing the walk-through method yielded 112 different species within 88 genera in 33 families (Table D1). Families represented by the most species were Asteraceae (sunflower) with 28 percent, Poaceae (grass) with 12 percent, Fabaceae (legume) with 9 percent, Cyperaceae (sedge) with 8 percent, and Lamiaceae (mint) with 3.5 percent of species present. The most common genera in each of these families are listed from more- to less-numerous, respectively, unless otherwise noted; Asteraceae: goldenrod, aster, sunflower, and ragweed (sunflower and ragweed equal); Poaceae: Kentucky and Canada bluegrass and brome (equal); Fabaceae: clover, vetch, and sweet clover (vetch and sweet clover equal); Cyperaceae: sedge, bulrush, and nutsedge (bulrush and nutsedge equal). Each species in the Lamiaceae belonged to a different genus.

The species located via the walk-through method consisted of 63 percent native species, 32 percent nonnative species, and 5 percent unknown (Table 8). The unknowns were not identifiable below family because they were not in bloom and their vegetative morphology was not distinctive enough to identify to genus or species. No species found were classified as endangered, threatened, or of special concern.

Twenty-four species were classified as invasive by the Minnesota County Biological Survey (Carlson 2010; MN DNR 2012a): common burdock, smooth brome, hedge bindweed, Canada thistle, bull thistle, quackgrass, black medick, white sweet clover, yellow sweet clover, white mulberry, wild parsnip, reed canary grass, timothy, common plantain, Canada bluegrass, Kentucky bluegrass, curly dock, yellow foxtail, perennial sowthistle, common dandelion, alsike clover, red clover, white clover, and common mullein (Table E1, G1).

Three species were classified as prohibited noxious species under the Minnesota Noxious Weed Law (Durgan 1998; MDA 2010): bull thistle, Canada thistle, and perennial sowthistle. There were no restricted noxious species. Seven species on the State secondary noxious species list were found: burdock, curly dock, common milkweed, yellow nutsedge, quackgrass, common ragweed, and giant ragweed. However these species are not currently included on Nicollet County's secondary noxious species list (Durgan 1998; MDA 2010) (Table E1, G1).

Four species were classified as Tier 1 Quality Indicators, according to the Minnesota County Biological Survey Native Indicator Species List (Carlson 2010; MN DNR 2012a): leadplant, common sneezeweed, prairie blazing star, and common golden alexander. Five species were identified as Tier 2 Quality Indicators (Carlson 2010; MN DNR 2012a): butterfly-weed, prairie heart-leaved aster, Indian grass, tall meadow rue, and Culver's root.

Twelve species were indicators of high-quality prairies (Curtis 1971): common water hemlock, Canadian tick-trefoil, northern bedstraw, sawtooth sunflower, prairie coneflower, black-eyed Susan, Missouri goldenrod, gray goldenrod, prairie cord-grass, tall meadow rue, Culver’s root, and common golden alexander.

Species diversity calculations using the Shannon-Wiener Index and the Simpson’s Index of Diversity could not be calculated for 2011 because there were no species abundance data. Species area curves, frequency, percent cover, and litter depth were also not calculated since the walk-through method is not designed to gather these data.

Mean-C and FQI for the Oak Leaf Lake Unit were calculated using all taxa on the site. An adjusted mean-C and FQI omitted the following species that are not expected to occur on prairies: (1) deciduous forest species (sugar maple and green ash), (2) emergent aquatic species (water lily, narrow-leaved cattail, and arrowhead), and (3) native species not listed by Ladd (2005) or located at Kasota Prairie (water smartweed, white vervain, white avens, orange jewelweed, common elder, prairie bulrush, catnip, arrow-leaved aster, and beaked sedge). These indices are reported in Table 8.

2012 Random-Sampling Method

The 2012 floristic survey utilizing the random-sampling method yielded 57 different species within 50 genera within 24 families (Table D1). All 57 species were located during the 2011 season using the walk-through method. Families represented by the most species were Asteraceae (sunflower) with 32 percent, Poaceae (grass) with 17 percent, Apiaceae (carrot) with 5 percent, Cyperaceae (sedge) with 5 percent, Fabaceae (legume) with 3 percent, Polygonaceae (smartweed) with 3 percent, and Salicaceae (willow) with 3 percent of species. The most common genera in each of these families are listed from more- to less-numerous, respectively, unless otherwise noted; Asteraceae: goldenrod, aster, sunflower, ragweed, and thistle (aster, sunflower, ragweed, and thistle equal); Poaceae: brome; Cyperaceae: bulrush and sedge. Each species in the Apiaceae belonged to a different genus.

The species located via the random-sampling method comprised 63 percent native species, 32 percent nonnative species, and 5 percent of unknown origin. The unknowns were not identifiable below family because they were not in bloom and their vegetative morphology was not distinctive enough to identify the species. No species found were classified as endangered, threatened, or of special concern.

Thirteen species were classified as invasive by the Minnesota County Biological Survey (Carlson 2010; MN DNR 2012a): common burdock, smooth brome, Canada thistle, bull thistle, white mulberry, wild parsnip, reed canary grass, common plantain, Kentucky bluegrass, curly dock, perennial sowthistle, common dandelion, and red clover.

Three species found were classified as prohibited noxious species under the Minnesota Noxious Weed Law (Durgan 1998; MDA 2010): bull thistle, Canada thistle, and perennial sowthistle. There were no restricted noxious species. Five plant species on the State secondary noxious species list were found (Durgan 1998; MDA 2010): burdock, curly dock, common milkweed, common ragweed, and giant ragweed. However these species are not currently included on Nicollet County's secondary noxious species list.

Two species were classified as Tier 1 Quality Indicators (Carlson 2010; MN DNR 2012a): common sneezeweed and common golden alexander. One species was classified as a Tier 2 Quality Indicator: Indian grass (Carlson 2010; MN DNR 2012a). Seven species were indicators of high-quality prairies (Curtis 1971): common water hemlock, sawtooth sunflower, prairie coneflower, black-eyed Susan, gray goldenrod, prairie cord-grass, and common golden alexander.

Shannon-Wiener Diversity Indices and Simpson's Diversity Indices for the random-sampling method are reported in Table 8.

The five most-frequently-occurring plant species were ranked for each of the three sampling events and for the full season; rankings are reported in Table 5. The random-sampling technique requires that all individuals be counted, therefore plants that were not in bloom were identified to species using vegetative characters whenever possible.

Table 5. Top five most frequently-occurring species for each sampling event (classified by blooming/fruiting periods I, II, and III) and for the full season during the 2012 growing season in randomly-located quadrats at the Oak Leaf Lake Unit (1 = the highest frequency; 5 = the lowest frequency).

Species	I	II	III	full season
smooth brome	1	2	1	1
wild bergamot	3	3	3	2
big bluestem		1	2	3
Kentucky bluegrass	2	4		4
sawtooth sunflower		5	4	5
common golden alexander	4			
reed canary grass			5	
Maximillian sunflower	5			

Cover class data for cover categories collected during the random-sampling method are given in Table 6.

Table 6. Mean cover class for each sampling event (classified by blooming/fruiting periods I, II, and III) and for the full season during the 2012 growing season in randomly-located quadrats at the Oak Leaf Lake Unit (Range is 1 – 6, with 1 = the lowest percentage of cover). "Other" includes rocks, logs, moss, etc.

Class/ Sampling event	bare ground	native grass	native forbs	nonnative grass	nonnative forbs	duff/ litter	other
I	2	2	2	3	2	2	1
II	1	3	2	3	1	1	1
III	1	3	3	3	2	1	1
Full Season	1	3	2	3	2	2	1

The mean litter depth was 2.6 cm for Period I (the early-blooming/fruiting), 2.1 cm for Period II (the mid-blooming/fruiting), and 1.9 cm for Period III (the late-blooming/fruiting). The mean litter depth was 2.2 cm for the full season.

Mean-C using all values calculated for the full season was 3.9 and the original FQI for the full season was 23.0. The adjusted mean-C for the full season was 4.0 and the adjusted FQI for the full season was 22.1 (Table 8).

Distribution of Species within Three Site Sections (A, B, C)

Section A consists primarily of mesic grassland and disturbed areas including the driveway, parking area, and boat access. Section B is transitional between mesic grassland and wetlands, which take up most of Section C (Figure B1). Table 7 shows the number and percent of species located during the 2011 and 2012 seasons using the walk-through and random-sampling methods, respectively, for each section within the site.

More than one-third of the high-quality indicator species (MCBS Tier 1, MCBS Tier 2, and/or *sensu* Curtis; Table G1) present at the study site were found in all three sections (Table 12). Similar numbers of indicator species were found in each of the three sections (A = 10, B = 12, and C = 11), with all but one indicator species found either only in one section or in all three sections. Six upland indicator species were found, with one (butterfly-weed) in Section A, one (gray goldenrod) in Section B, one (leadplant) in Section C, one (prairie heart-leaved aster) in Sections A and B, and two (gray-headed coneflower and Missouri goldenrod) in Sections A, B, and C. Three facultative upland indicator species were found, with one (Canadian tick trefoil) located in Section A and

Table 7. Species located in Sections A, B, and C of the Oak Leaf Lake Unit during the walk-through method in 2011 (112 species) and the random-sampling method in 2012 (57 species).

# of species	2011		2012	
	# of species	% of species	# of species	% of species
in A	42	38%	19	33%
in B	12	11%	4	7%
in C	17	15%	8	14%
in both A & B	6	5%	2	4%
in both A & C	0	0%	0	0%
in both B & C	8	7%	1	2%
in A, B, & C	27	24%	23	40%

two (Indian grass and black-eyed Susan) in Sections A, B, and C. Four facultative indicator species were found, with three (prairie blazing star, Culver's root, and northern bedstraw) located in Section B and one (common golden alexander) in Sections A, B, and C. Four facultative wetland indicator species were found, with two (purple meadow rue and prairie cordgrass) located in Section C and two (common sneezeweed and sawtooth sunflower) in Sections A, B, and C. The only obligate wetland indicator species (common water hemlock) was located in Section C.

Most species were either present exclusively in one section (64 percent) or occurred in all three sections (24 percent). More than one-third of the species located in all three sections were native perennial forbs with mid-range C-values. All but one of the early-successional species occurred in Section A (with over half found exclusively in Section A), about one-fourth also occurred in Section B, and only one occurred in Section C.

DISCUSSION

The primary objective of this study was to perform a floristic survey and to gather baseline data for the Oak Leaf Lake Unit. This was accomplished during two growing seasons using two methods: a walk-through method during 2011 and a random-sampling-in-quadrats method during 2012. Data were used to assess the ecological quality of the site by calculating diversity and quality indices, and using Jaccard's indices to compare the study site's flora to that of other prairies in the region. Indices generated by the two data collection methods were compared.

Flora at the Oak Leaf Lake Unit

The flora at the 20-year-old Oak Leaf Lake Unit is typical of Midwestern mesic to wet prairies. The site is dominated by long-lived herbaceous perennials. Ladd (2005) provides a list of 988 Midwestern tallgrass prairie species that he separates into "physiognomic classes" based on habit and duration. These are ranked by percentage with perennial forbs, annual and biennial forbs, and grasses (including all grasslike species) making up about 52, 17, and 22 percent of species, respectively (Ladd 2005). The same classes at the Oak Leaf Lake Unit comprise 49, 16, and 21 percent, respectively. The three most important families are Asteraceae including species in sunflower (genus *Helianthus*), aster (genus *Symphyotrichum*), and goldenrod (genus *Solidago*), etc., Poaceae, including big bluestem, switchgrass, Indian grass, prairie cord grass, etc., and Fabaceae, including lead plant, Canadian tickfoil, and American vetch (Tables D1, E1).

Eight percent of species at the study site are tree species compared to 1.6 percent of species on Ladd's (2005) list. The study site is in the ecotone between prairie and deciduous forest biomes so there is sufficient moisture to support tree species typically found in forests including native *Acer saccharum* (sugar maple) and *Fraxinus pennsylvanica* (green ash), and naturalized nonnatives *Morus alba* (white mulberry) and *Pyrus malus* (crab apple), which are growing on the study site but are not typical of prairies (Curtis 1971; Ladd 2005). The study site is close to stands of deciduous forest that act as seed sources. Many tallgrass prairies are located farther away from the deciduous forest biome and/or they are too dry to support these tree species (Curtis 1971; Tester 1995; Kline 2005; Ladd 2005).

Of 112 species located on the site, at least 70 are native; 59 of these are prairie species. Forty-seven prairie species found at the site have been assigned coefficients of conservatism (C-values) between 1 and 10; such species factor into the calculation of mean-C and FQI (Tables 10, D1, E1). Seventeen prairie species at the Oak Leaf Lake Unit have C-values of 6 to 10, which indicates high quality; a C-value of 10 indicates a species that almost always occurs on an undisturbed high-quality site (TNGPFQAP 2001). Species with C-values of 5 can usually be located in natural areas, but may also be found in disturbed areas (TNGPFQAP 2001). Eighteen indicator species (Curtis 1971; Carlson 2010; MN DNR 2012a) fill niches in mid- and late-successional stages of a prairie (Tables E1, G1), which indicates the site is mature. Tier 1 high-quality indicators leadplant and prairie blazing star are among the most sensitive or difficult to establish species (Carlson 2010; MN DNR 2012a).

Because the site is in the ecotone between prairie and deciduous forest biomes, high-quality indicators, such as sugar maple and green ash, with C-values of 10 and 5, respectively, increase mean-C and the FQI for the site. These species' C-values were omitted from calculations of adjusted quality indices because they are indicators of high-quality deciduous forests not prairies (Curtis 1971, Ladd 2005). With the site adjacent to a lake, other high-quality indicators, such as water lily, with a C-value of 9, also increase mean-C and the FQI for the site and were omitted from calculations of quality indices because they are indicators of high-quality aquatic habitats not prairies (Curtis 1971, Ladd 2005). TNGPFQAP (2001) lists other species not expected to be found in prairies like orange jewelweed with a C-value of 4, which is usually found near woods or in damp habitats. Such species, not listed by Ladd, and not found at Kasota Prairie were also omitted from calculations of adjusted quality indices. The mean-C and FQI were originally calculated for all species listed by TNGPFQAP (2001). Adjusted mean-C and FQI were calculated omitting 14 non-prairie species (see p. 48). The adjusted mean-C and FQI only include species that are adapted to and occur in prairie habitats so that the site's quality can be accurately assessed.

Some prairie species located at the study site were not assigned C-values by TNGPFQAP (2001), which includes the flora of North and South Dakota. Ladd (2005) provides C-values for species from other states' lists, which allowed me to assign C-values if they were missing. I used C-values from the Illinois list first, and if Illinois did not list a species, I selected a C-value from the next closest state. For example, marsh spikerush is a high-quality species found at the study site, but not assigned a C-value by

TNGPFQAP (2001). Illinois assigns it a C-value of 8, which may not be in perfect accord with its perceived value in Minnesota, but it is better than omitting the species altogether. Omitting high-quality prairie species from calculations of mean-C and FQI will lead to an underestimate of the quality of the site.

A comparison of the FQI using all taxa and the adjusted FQIs brings to light the problem of calculating these indices without carefully considering whether the species present are typical representatives of the community of interest, in this case, a prairie. Including such taxa may lead to an overestimation of the quality of the site. Although the original mean-C and FQI calculated for the Oak Leaf Lake Unit are not much different from the adjusted indices, the original FQI of 36.1 hovers at the very edge of being inadequate (threshold = 35) in native species and biodiversity. The adjusted FQI of 32.2 gives a clearer signal that the quality of the site is low (Table 8). These results suggest that caution should be taken to ensure the species included in mean-C and FQI are typically found in the community of interest.

No rare or endangered species were located, but that does not mean rare or endangered species do not occur at the study site. The walk-through method might have turned up rare species if they had been in bloom and/or clearly visible during visits. Some rare species have short blooming periods that may have occurred between visits or before June 13 when the first visit was made. Given the constraints of the random-sampling method, rare species would only be listed if they were present in a quadrat.

Early-Successional Species and Weeds

Species that fill early-successional niches are able to endure environmental extremes such as high heat, lack of shade, and dry soil, which may have low organic matter and nutrient content. Such conditions are common in disturbed areas. These species cover bare ground, reducing erosion and eventually increasing soil organic matter. They provide shade, thereby keeping soil cooler and reducing soil water loss, which increases germination rates and seedling survival rates of mid- and late-successional species. Foster and Tilman (2000) show that as the age of a prairie increases, the species richness of annual and nonnative early-successional species declines and the species richness of perennial native forb and grass species increases.

Of the 23 annual, biennial, to short-lived perennials that are generally considered early-successional species found at the site, 16 are nonnative, 11 are classified as invasive, and four are State Secondary Noxious species (Gleason and Cronquist 1991; MDA 2010, 2012; University of Minnesota Extension 2015a, 2015b, 2015c) (Table G1). Fourteen of these species are confined to Section A of the site where disturbed areas along the driveway and boat launch are located (Table G1).

Four short-lived native species at the site, orange jewelweed, rough fleabane, tall lettuce, and black-eyed Susan have C-values of 4, 3, 6, and 5, respectively. Orange jewelweed was omitted from the adjusted FQI because it is commonly found in woodlands and ditches. It is not included in Ladd's (2005) list of prairie species. Rough fleabane, tall lettuce, and black-eyed Susan are expected on prairies and their C-values contribute to the site's FQI. Other native annual species, common and giant ragweed, and horseweed, are viewed as undesirable "weeds" in agricultural settings and gardens so they receive C-values of 0. The ragweeds cause hay fever.

Of 24 species classified as invasive by MCBS (Carlson 2010; MN DNR 2012a) and/or as prohibited noxious species (MDA 2010, 2012), and State secondary noxious species (MDA 2010, 2012), all but three species, (common and giant ragweed, and common milkweed) are nonnative (Table G1). Of these, 11 are short-lived, early-successional species. Perennial invasive/noxious species, including reed canary grass, hedge bindweed, yellow sweet clover, white sweet clover, and Canada thistle (Table G1) may threaten the long-term quality of the site. Invasive perennials have the potential to outcompete and replace native species and disrupt entire communities, which decreases plant biodiversity and the overall quality of prairies. The strong presence of native perennial species at the site is encouraging because they will resist displacement by invasive species better than annuals and short-lived perennials (Foster and Tilman 2000).

Although common milkweed is listed as a State secondary noxious species, perhaps because it spreads very aggressively by runners, it is native and an integral part of the community as a larval host and specialized species for pollinators such as *Danaus plexippus* (monarch butterfly) (Kevan et al. 1989). Propagation of common milkweed is now encouraged, mostly in landscape and horticulture settings, to increase declining monarch butterfly populations. Monarch butterflies lay their eggs on common milkweed so that larval stages can feed on the plant and take up secondary compounds that protect the plant from insect herbivores; these, in turn, make monarch caterpillars repulsive to their predators (USDA 2012c).

Assessing the Site's Diversity and Quality

Because two floristic data sets were collected using two different methods during the 2011 and 2012 growing seasons, two sets of indicators and indices of diversity, and quality were calculated for the two full seasons. Each season was also broken into early-, mid-, and late-blooming/fruiting periods for which indices were calculated. Table 8 summarizes these data.

Table 8 *(on next page)*. Summary of floristic data collected at the Oak Leaf Lake Unit with quality-assessment indices mean-C and FQI derived from them for entities located by two methods (WT = walk-through in 2011 and R = random-sampling in 2012) for the full season and for three blooming/fruiting periods. Jaccard's coefficients (C_j) indicate similarity of entities located by WT and R methods. "Total # unique to the year" refers to the number of species that were *only* found in the year indicated. Shannon-Wiener Diversity Indices (*H*) and Simpson's Index of Diversity (*D*) were calculated for each of the three blooming/fruiting periods and the full season. The usual range of *H* is 1.5 to 3.5, with species diversity increasing as *H* increases. *D* ranges from zero to one, with diversity increasing as *D* increases.

Table 8. Summary of floristic data collected at the Oak Leaf Lake Unit by two methods (WT = walk-through in 2011 and R = random-sampling in 2012) for the full season and for three blooming/fruiting periods. Full caption on previous page.

	I		II		III		Full Season	
	WT	R	WT	R	WT	R	WT	R
# sampling of events	4	1	5	1	4	1	13	3
# families	16	16	16	7	16	6	33	24
% families	48%	67%	48%	29%	48%	25%	100%	100%
# species located for first time	41	44	40	7	31	6	112	57
% species	37%	77%	36%	12%	28%	11%	100%	100%
# native	20	25	28	6	22	5	70	36
% native of total species located	18%	44%	25%	10%	20%	9%	63%	63%
# nonnative	20	16	11	1	5	1	36	18
% nonnative of total species located	18%	28%	10%	2%	4%	2%	32%	32%
# unknown	1	3	1	0	4	0	6	3
% unknown of total species located	1%	5%	1%	0%	3%	0%	5%	5%
total # species unique to year	-	-	-	-	-	-	55	0
# MCBS indicator species	2	2	4	0	3	1	9	3
# Curtis indicator species	5	6	5	0	2	1	12	7
# invasive species	14	11	7	2	3	0	24	13
# MDA noxious species	3	7	5	1	2	0	10	8
# other weed species	10	7	6	1	1	0	17	8
# of early-successional species	11	7	11	5	1	1	23	13
original mean-C	4.1	3.7	4.6	4.3	4.5	4.3	4.4	3.9
adjusted mean-C	4.5	3.9	4.6	3.7	3.9	4.4	4.3	4.0
original FQI	17.0	18.6	24.4	8.5	20.5	10.6	36.1	23.0
adjusted FQI	17.3	18.8	21.5	6.4	16.7	9.8	32.2	22.1
H	-	3.0	-	2.7	-	2.6	-	2.3
D	-	0.923	-	0.905	-	0.903	-	0.924
C_j	0.25		0.07		0.03		0.51	

In every measure and index (except diversity indices, *H* and *D*, which cannot be calculated using 2011 data), the walk-through method yielded a value indicating greater richness and quality. Because a flora consisting largely of herbaceous perennials is not expected to change much from season to season, the overall quality of Oak Leaf Lake Unit's flora will be discussed using data derived from the 2011 walk-through method. A comparison, including strengths and weaknesses of the two data collection methods, will be made and discussed below.

To further assess the diversity and quality of the flora of the Oak Leaf Lake Unit, I calculated Jaccard's coefficients to compare its flora with floras at 11 predominantly-grassland sites. Schiebout et al. (2008) concluded that locations closer to each other have more similar taxa, so the 11 sites were chosen for their proximity to my site. Species lists for the sites came from Kramer (1975) and MN DNR (2016b). Table 9 reports Jaccard's coefficients, proximity, number of similar habitats, adjusted mean-C, and adjusted FQI for the 12 sites. As predicted by Schiebout et al. (2008), sites closest to the study site had the highest Jaccard's coefficients, although none of the coefficients indicated very high similarity. Oak Leaf Lake's flora is most similar to that of the Kasota Prairie, a 42-acre site made up of native mesic/tallgrass prairie and restored prairie after grazing. Kasota Prairie's FQI of 65.3 indicates it is a very high-quality site. The two sites are closest to each other and have the greatest number of similar habitats and elevation. For these reasons, Kasota Prairie was chosen as a representative site of a high-quality prairie to compare to the study site. It is important to point out that the species list from Kasota

Prairie is more than 40 years old; species composition and richness may have changed over the years.

Although nearby Rasmussen Woods has a similar flora based on Jaccard's coefficient, it was not chosen because Rasmussen has a large deciduous forest component with many woodland species and its grassland species are not indicative of high-quality prairies. The other sites were not chosen because they were too far away from the study site, shared lower species similarities based on Jaccard's coefficients, and/or had too few habitats in common.

Table 9. Jaccard's coefficients (C_j) comparing the flora of the Oak Leaf Lake Unit with floras of 11 predominantly-grassland sites within Minnesota (10 are MN DNR scientific and natural areas [SNAs]) ranked from highest to lowest similarities. Their proximity and number of similar habitats to the Oak Leaf Lake Unit are also listed. The mean C-value and floristic quality index (FQI) were also calculated for each site.

	C_j with Oak Leaf Lake Unit	proximity to Oak Leaf Lake Unit (km)	# of habitats similar to Oak Leaf Lake Unit	adjusted $\overline{C}$	adjusted FQI
Oak Leaf Lake Unit	-	-	-	4.3	32.2
Kasota Prairie SNA	0.20	5	3	5.3	65.3
Rasmussen Woods Nature Area	0.18	19	3	4.7	52.4
Cottonwood River Prairie SNA	0.17	90	3	5.3	55.0
Cedar Mountain SNA	0.14	72	3	5.6	67.4
Rock Ridge Prairie SNA	0.13	89	1	5.7	51.0
Joseph A. Tauer Prairie SNA	0.12	45	2	6.0	41.7
Osmundson Prairie SNA	0.12	97	1	5.8	35.5
Yellow Bank Hills SNA	0.11	240	1	5.3	39.4
Clinton Prairie SNA	0.08	241	2	5.9	34.7
Bonanza Prairie SNA	0.06	258	2	6.2	47.6
Blue Devil Valley SNA	0.01	137	1	4.1	14.7

Species Richness

Although floras at the study site and Kasota Prairie had the greatest C_j value, 0.20 does not indicate high similarity. The Oak Leaf Lake Unit supports 112 different species of which, 63 percent are native. Kasota Prairie supports 187 different species, of which 82 percent are native. The Kasota Prairie site is remnant native prairie that was established as an SNA in 1984, while the Oak Leaf Lake Unit was once agricultural land restored to prairie in 1994. Because Kasota Prairie has not been disturbed much since presettlement times it is more likely to have greater species richness including many more sensitive and late-successional native species, like rattlesnake master, a facultative wetland species with a C-value of 8 (Ladd 2005), which is found at Kasota Prairie, but not at the study site (Kramer 1975). The sites do share some high-quality indicator species, such as leadplant, Indian grass, and Culver's root. Both sites also have invasive/noxious species in common, such as reed canary grass, Canada thistle, and yellow and white sweet clover.

Table 10 summarizes moisture requirements for native species in two classes, sensitive species with C-values between 6 and 10 and less sensitive species with C-values between 1 and 5, for the Oak Leaf Lake Unit and Kasota Prairie. While 38 percent of Kasota Prairie's 103 native species are adapted to dry uplands, only 13 percent of Oak Leaf Lake's 47 native species are (Table 10). In contrast, Oak Leaf Lake has two high-quality obligate wetland species, while Kasota only has one. This suggests that Kasota Prairie has drier habitats to support obligate upland species. Ladd's (2005) data show that nearly half of prairie species are adapted to dry upland habitats that are found across the Great Plains. Kasota Prairie and the study site share nine obligate upland species including *Amorpha canescens* (leadplant), and *Ascelepias tuberosa* (butterfly weed). However Kasota Prairie is home to 47 additional obligate upland species not found at the Oak Leaf Lake site, including *Anemone patens* (pasqueflower), *Bouteloua curtipendula* (side-oats grama), and *Petalostemon purpureum* (purple prairie clover).

Mean C-values and floristic quality index (FQI) at Oak Leaf Lake and Kasota Prairie differed. The Oak Leaf Lake Unit's mean-C value was 4.3 and the FQI was 32.2. The Kasota Prairie's mean-C value was 5.3 and the FQI was 65.3 (Table 9). Kasota Prairie's higher mean-C can be attributed to it having a higher percentage of late-successional high-quality native species than the Oak Leaf Lake Unit. Fifty-nine percent of Kasota Prairie's native species have C-values of 6 to 10 compared to 36 percent of Oak Leaf Lake's species in the same category (Table 10). The large differences between the FQIs for the two sites is also due to the difference in numbers of native species at the sites. Kasota Prairie has 103 native species compared to 47 at the Oak Leaf Lake Unit. The adjusted FQI for the study site indicates it has an insufficient number of native species and inadequate biodiversity (Swink and Wilhelm 1994; Higgins et al. 2001). An increase in invasive species could suppress native species and decrease the FQI at the Oak Leaf Lake Unit even further. Loss of plant diversity would mean fewer pollinating bees and butterflies, fewer insects for birds and their young to feed on, and fewer animals, such as mice, voles, fox, snakes, gophers, and deer, essential to the food web.

Table 10. Species at Oak Leaf Lake Unit and Kasota Prairie SNA with C-values between 1 and 10 organized into wetland rating classes per the Army Corps' wetland classification system (Lichvar et al. 2014) with Ladd's (2005) numerical classification in parentheses.

	Oak Leaf Lake Unit					**Kasota Prairie SNA**				
Wetland class	Spp in class	C-values 6 to 10	% in class	C-values 1 to 5	% in class	Spp in class	C-values 6 to 10	% in class	C-values 1 to 5	% in class
UPL (5)	12	6	12.8	6	12.8	52	39	37.9	13	12.6
FACU (4 to 1)	13	4	8.5	8	17.0	23	11	10.7	12	11.7
FAC (0)	3	2	4.3	1	2.1	4	2	1.9	2	1.9
FACW (-1 to -4)	11	3	6.4	7	14.9	18	9	8.7	9	8.7
OBL (5)	8	2	4.3	6	12.8	6	1	1.0	5	4.9
Total	47	17	36.2	28	59.6	103	62	59.2	41	35.0

Species Diversity

Shannon-Wiener and Simpson's Diversity Indices can only be calculated when species abundance data are available, therefore they are derived from 2012 data. Both indices are measures of species diversity, with the Shannon-Wiener Index measuring species richness and evenness and the Simpson's Index of Diversity placing more weight on species abundance than on species richness. It is important to note that the Shannon-Wiener and Simpson's Diversity Indices calculated for the site only included 57 out of the 112 species identified at the site.

The Shannon-Wiener Diversity Index for the full season is close to the midpoint indicating "medium" diversity for the site (Table 8). The Simpson's Index values indicate overall high diversity at the study site (Table 8). Although the indices show medium to high levels of diversity at the Oak Leaf Lake Unit, they do not take into account the quality of the species. The species used in the calculation of these diversity indices included more than half of the low-quality species at the site, including 13 invasive species. This is a weakness of these indices: diversity can appear to be adequate or high, but this does not tell the whole story. Without knowing what species are present, there is no way to judge the quality of the site. This also highlights a risk of the random-sampling method, which is failure to capture all species present at a site. When species are not included, diversity is underestimated. Furthermore, species that fall outside quadrats may be rare. Rare species are often indicators of high quality sites. Failure to take them into account may cause an investigator to overlook a critically important site. Greater high-quality species diversity is ecologically important because complex communities are more stable (Foster and Tilman 2000). They provide more ecological niches and more complex food webs. Diverse communities are resilient; they are better able to adapt and thrive in response to environmental changes.

My data indicate that grasses made up a higher percentage of cover than forbs at the Oak Leaf Lake Unit (Table 6). Although grasses are more common on the study site (cover class 3/6), forbs were not scarce (cover class 2/6). Forbs represented a majority of the total species located (65 percent), contributing importantly to the diversity of the site. However, a lack of forbs is a concern in restored prairies (Volkert 1992; Sample and Mossman 1997) because they are essential for nesting and brooding structures for some bird species (Volkert 1992; Sample and Mossman 1997) and are the primary habitats for many invertebrates, which in turn are an important food source for grassland birds and their broods (Buchanan et al. 2006). Competition from established grasses can suppress forb establishment. Baer et al. (2002) found that grasses accounted for less than 10 percent of total plant cover in restored grasslands that were four or fewer years old; however, by year six, grasses made up more than 80 percent of total plant cover and forbs were scarce. Camill et al. (2004) found a similar pattern and concluded species richness was lower on restored grasslands than on undisturbed prairies because of the dominance of grasses.

Comparison of Three Sections Within the Site

The Oak Leaf Lake Unit gradually slopes from mesic to wetland with a disturbed area at the higher edge. The site is divided into three roughly-equal-sized sections: Section A consists primarily of mesic grassland and disturbed areas, Section B is transitional between mesic grassland and wetlands, which take up most of Section C (Figure B1).

Indicator species were located in each section; finding indicator species in all three sections suggests that the entire site offers high-quality species the conditions they need to flourish. The number of early-successional species decreased from Section A (with over half found exclusively in Section A) to Section B to Section C. This reflects the gradient from disturbed through undisturbed mesic to more restrictive wetland habitats at the site.

Section A had the greatest species richness, which is expected; this section contains the widest variety of habitats including a disturbed area that is open to early-successional species, including annuals and short-lived species (Tables 7, D1). More than one-third of the species found exclusively in Section A are native perennial forbs with C-values from 1 to 9, indicating a highly-variable assemblage that reflects the patchiness of habitats in this section. Of 24 invasive species on the site, exactly half of them were located exclusively in Section A and 11 of those are early-successional species such as clover species, dandelion, and common plantain. Few early-successional invasive species were located in Sections B and C, most likely because the sections' relatively dense established vegetation does not provide the open conditions these species thrive in. Even the ubiquitous common dandelion was found much less abundantly in Sections B and C. Perennial invasive species such as Canada thistle, perennial sow-thistle, and reed canary grass are found throughout the site; like native herbaceous perennials, they may favor more stable conditions. A substantial stand of reed canary grass is found in Section C. This aggressive invasive species prefers mesic to wet soils; it is likely crowding out the native species while preventing or deterring the establishment of any new species, including other invasive species.

Species differ in their ability to thrive in dry to wet substrates and their moisture requirements and distributions can provide information about habitat conditions on a site. Table 11 summarizes the moisture preferences and locations within the site (Sections A, B, and C) for all species at the Oak Leaf Lake Unit. Table 12 summarizes the moisture preferences and locations of high-quality indicator species at the site.

Table 11. Moisture preference for all species located in each section of the Oak Leaf Lake Unit according to the United States Army Corps of Engineers Region 3 Midwest 2014 Wetland Plant List (Lichvar et al. 2014) and Ladd's (2005) coefficient of wetness (5 to -5, with 5 being the driest and -5 being the wettest) are obligate wetland (OBL = -5, almost always found in wetlands), facultative wetland (FACW = -1 to -4, usually found in wetlands, but may occur in non-wetlands), facultative (FAC = 0, found in wetland and non-wetlands), facultative upland (FACU = 1 to 4, usually found in non-wetlands, but occur in wetlands), and obligate upland (UPL = 5, almost never found in wetlands).

Section	Wetland Code for All Species					
	OBL	FACW	FAC	FACU	UPL	unknown/ not listed
in A	3	5	8	14	4	8
in B	1	1	3	3	1	3
in C	4	3	2	2	2	4
in both A & B	0	1	0	3	1	1
in both A & C	0	0	0	0	0	0
in both B & C	2	1	0	1	0	4
in A, B, & C	1	4	5	12	3	2

Table 12. Moisture preference for indicator species located in each section of the Oak Leaf Lake Unit according to the United States Army Corps of Engineers Region 3 Midwest 2014 Wetland Plant List (Lichvar et al. 2014) and Ladd's (2005) coefficient of wetness (5 to -5, with 5 being the driest and -5 being the wettest) are obligate wetland (OBL = -5, almost always found in wetlands), facultative wetland (FACW = -1 to -4, usually found in wetlands, but may occur in non-wetlands), facultative (FAC = 0, found in wetland and non-wetlands), facultative upland (FACU = 1 to 4, usually found in non-wetlands, but occur in wetlands), and obligate upland (UPL = 5, almost never found in wetlands).

Section	Wetland Code for High-Quality Indicator Species				
	OBL	FACW	FAC	FACU	UPL
in A	0	0	0	1	1
in B	0	0	3	0	1
in C	1	2	0	0	1
in both A & B	0	0	0	0	1
in both A & C	0	0	0	0	0
in both B & C	0	0	0	0	0
in A, B, & C	0	2	1	2	2

Butterfly-weed and Canadian tick-trefoil are two high-quality indicator species (MCBS Tier 1, Tier 2 and/or *sensu* Curtis) found exclusively in Section A (Table G1). The former is an upland species and the latter a facultative upland species (Tables 12, D1, E1, G1). Indicator species found exclusively in Section B were upland species gray goldenrod and facultative species prairie blazing star, Culver's root, and northern bedstraw. Indicator species found exclusively in Section C were upland species leadplant, facultative wetland species purple meadow rue and prairie cordgrass, and obligate species common water hemlock. The occurrence of these species generally reflects the gradient from higher to lower elevation and the moisture gradient from mesic in Section A and wet-mesic to wet in Section C. All of the soil types at the study site have high available water capacity, are poorly drained, and are in close proximity to a lake, and therefore are probably most often mesic, wet-mesic, and/or wet. Half of Kasota Prairie's native species with C-values of 1-9 are obligate upland species while only a quarter of the species at the Oak Leaf Lake Unit are in this class (Tables 10 and 11). If the study site had true dry upland areas, we would expect to find more upland species like those found at Kasota Prairie; instead the study site has more facultative species, such as Culver's root, common golden alexander, northern bedstraw, and prairie blazing star, facultative wetland species such as sawtooth sunflower, common sneezeweed, prairie cordgrass, and tall meadow rue, and obligate wetland species, such as common water hemlock, swamp milkweed, and Bebb's sedge (Curtis 1955).

Effects of Weather and Climate on the Flora at the Oak Leaf Lake Unit

Using data from MRCC (2014), I found that mean daily precipitation for August, September, and October 2011 and June through September 2012 were significantly lower than the 30-year (1981-2010) means for those months (Figure 2). Mean daily temperatures for July 2011 and May, July, and October 2012 were significantly higher than the 30-year (1981-2010) means for those months (Figure 3). Higher temperatures and drought conditions during my survey years may be indicative of climate change in our region, which may have long-term consequences for the site.

Foster and Tilman (2000) found a decline in species richness in their grassland test plots by an average of 37 percent during drought conditions in 1988 through the elimination of scarce annual species and rare species. Seventy-two percent of Midwestern tallgrass species consist of herbaceous perennials; only 16 percent of species are annuals (Ladd 2005). In general, common herbaceous perennial species will not be lost during one season of drought because they survive winter by storing carbohydrates in perennating organs such as rhizomes and storage roots (Raven et al. 2005). When new shoots emerge in the spring, they are relying on energy stored the previous year (Raven et al. 2005). The stature and vigor of individuals may be affected by dry years, but it will likely take a series of very dry years before these tough, resilient species are killed. Rare perennial species may be less tolerant of environmental extremes. Annual species complete their life cycles in a single growing season. If it is too dry, seeds may not germinate and seedlings and/or plants may not survive to produce seeds. Rare annual species are particularly vulnerable. Tilman and Haddi (1992) suggest the loss of rare species, due to increased drought frequencies as a result of climate change, is a threat to biodiversity. The Oak Leaf Lake Unit flora consists of 82 percent perennial forbs and grasses; its annual species are not rare, nor are most high quality indicators. Although the drought conditions from July to October of 2012 were severe, they likely did not decrease species richness at the site because perennial forbs and grasses are less likely to be lost to short-term drought conditions, especially when they are abundant (Tilman and Haddi 1992).

In 2011 big bluestem plants were about 0.9-1.2 m tall, but in 2012 averaged about 1.4 m, with some as tall as 1.8 m. Big bluestem may be at or near maturity in some portions of the site because the maximum height of big bluestem at maturity (approximately 20 years) is about 1.8 m tall. During 2012, big bluestem was patchy and mixed with smooth brome, which was shorter than it was the previous year, averaging about 15 cm high. Big bluestem is a facultative species (Lichvar et al. 2014), meaning it can occur in wetlands and non-wetlands. The root systems of native prairie grasses like big bluestem are generally much larger than those of nonnative grasses reflecting their adaptation to the relatively dry prairies of the Great Plains. The roots of big bluestem can reach nine feet deep and can access water and nutrients unavailable to shorter-rooted nonnative species, such as smooth brome, with root systems only about one foot deep (MN DNR 2016c). The big bluestem plants may have tolerated drought conditions during 2012 better than the nonnative smooth brome on the site. However, the stand of invasive reed canary grass in Section C expanded from 2011 to 2012.

I noticed more patches of native perennial forbs in 2012 than I did in 2011, especially of sawtooth sunflower, Canada goldenrod, wild bergamot, and Maximillian sunflower. The one patch of Carolina rose had become larger. There were fewer early-successional species, black-eyed Susan and wild parsnip individuals in 2012 than in 2011. These short-lived species may suffer more than perennials during drought years.

Comparison of Data Collection Methods

Assessing the diversity of the study site using data collected in 2011 (walk-through method) and 2012 (random-sampling method) yielded different results (Table 8). Of the 112 unique species located on the site in 2011, only about half of them were relocated using the random-sampling method in 2012 (Table 8). No new unique species were located in 2012 (Table 8). While a greater number of invasive species, MDA noxious species, and other undesirable species were located by the walk-through method, they were balanced by increased numbers of high-quality MCBS and Curtis indicator species. My study indicates that mean-C and FQI indices derived from walk-through data will provide a more accurate assessment of the quality of the site because they are based on species richness. Using data gathered by the random-sampling method will seriously underestimate these quality indicators (Table 8).

Choosing the Best Sampling Method and Time to Collect Data

A thorough walk-through requires frequent visits to a site so that species with short blooming or other reproductive periods will be noted and included in the flora.

Random-sampling using quadrats is also time consuming because individual plants must be counted and measured within their quadrats.

The early-blooming/fruiting period (Period I) yielded the greatest species richness for both the walk-through and random-sampling methods with fewer new species being discovered during subsequent periods. Because identification of flowering plants relies heavily on characters of flowers, the collection dates for species at the Oak Leaf Lake Unit roughly correspond to the beginning of species' blooming periods, especially for data collected in 2011. Prairie species in Minnesota begin to bloom in mid April (Kramer 1975) so my Period I captured a 12-week blooming window, which is twice the length of either Period II (five weeks) or Period III (six weeks). This might explain, in part, why the first blooming period yielded more species. It should be noted, however, that prairie species tend to bloom later in the season than herbaceous woodland species. Kramer (1975) only lists four species at Kasota Prairie that bloomed before the end of May so it is unlikely that I missed many, if any species by starting my surveys in early to mid June.

Kramer's (1975) blooming calendar indicates 57 of the 111 species he observed (51 percent) came into bloom between May 23 and July 9, which is roughly equivalent to my Period I. I captured 37 and 77 percent of species at the Oak Leaf Lake Unit during 2011 and 2012 during Period I, respectively (Table 8). These percentages are quite different from each other with Kramer's (1975) observation at Kasota Prairie falling about half-way between them. Early spring temperatures during 2011 and 2012 may explain these discrepancies. Although the differences are not significant, mean daily temperatures for April and May of 2011 were about 1° C cooler than the 30-year means

(Table 4, Figure 3). The growing season in 2011 was unusually short, lasting only 135 days as compared to the 30-year mean of 158 days (Figure 5); the last spring frost on May 4th was six days later than the 30-year mean of April 29 (MRCC 2014). That only 37 percent of species were located within Period I in 2011 may, in part, be explained by colder spring temperatures. Early-blooming species are very sensitive to warmer or cooler temperatures, blooming one to two weeks earlier or later, respectively (A. Mahoney, personal communication, March 20, 2016). During 2012, the mean daily temperature for April was 1° C warmer than the 30-year mean and May was statistically significantly warmer than the 30-year mean (Table 4, Figure 3). This may explain why 77 percent of species were noted in Period I in 2012.

Blooming periods at Kasota Prairie (Kramer 1975) show the same pattern I observed at the Oak Leaf Lake Unit: fewer “new” species (as represented by species coming into bloom) were discovered as the season progressed. Thirty-five percent of species at Kasota came into bloom during my Period II and 20 percent came into bloom during my Period III as compared to 35 and 12 percent of species at the Oak Leaf Lake Unit in Period II and 28 and 11 percent in Period III for 2011 and 2012, respectively. Despite the fact that Period I had the greatest species diversity, I conclude that if only one visit per growing season could be performed, it should occur later in the season because blooming seasons can last quite a while. Kramer’s (1975) calendar indicates that of 74 species that came into bloom in mid June, 30 (41 percent) were still in bloom by mid August and 17 (23 percent) were still in bloom during the first week of September. Even if some species are past their blooming/fruiting periods, dried flowers or fruits on the plants often allow them to be identified.

My experiences suggest that choosing between the walk-through or random-sampling methods is dependent upon the purpose of the study. If one is attempting to create a flora for a relatively small area or if one is searching for rare species, or observing habitat heterogeneity, the walk-through method may be preferable. If one is looking for a "snapshot" of the overall characteristics of the vegetation, quantitative data for statistical analyses, or the area is large, random-sampling in quadrats is preferred.

CONCLUSION

The primary objective of this study was to perform a floristic survey and to gather baseline data for the restored prairie at Oak Leaf Lake Unit. This was accomplished during two growing seasons using two methods: a walk-through method during 2011 and a random-sampling-in-quadrats method during 2012. The secondary objective was to assess the ecological quality of the site by comparing species richness, mean-Cs, and FQIs with other prairies in the region.

My first null hypothesis, that species richness and FQI for the study site will not differ from the species richness and FQI of other prairies in the region, is rejected. My alternative hypothesis, that the study site has lower species richness and FQI than other prairies in the region, is also rejected. The Oak Leaf Lake Unit had greater total species richness than seven out of the 11 predominantly-grassland sites it was compared to. The site had the third highest species-to-acres ratio out of the 12 sites. FQI for the Oak Leaf Lake Unit was higher than one of the other 11 sites. One factor leading to greater species richness but lower FQI may be the presence of disturbed areas in Section A, which provide niches for early-successional species with low C-values. These species will drive down an FQI in comparison to FQIs of less-disturbed mature sites with greater proportions of higher-quality native species.

The Oak Leaf Lake Unit supports many fewer high-quality prairie species than the Kasota Prairie, which also contributes to its inadequate FQI. Ladd (2005) shows that 58 percent of tallgrass prairie flora is adapted to dry upland habitats that characterize the prairie biome across most of the Great Plains. Only 14 percent of prairie species listed by Ladd (2005) occur in wetlands. Wet prairie areas are often calcareous fens or other highly-specialized habitats that support assemblages of rare species adapted to such conditions. Prairies in south central Minnesota where the Oak Leaf Lake Unit is located must usually be maintained by fire because annual precipitation is sufficient for succession to a climax deciduous forest. Although the Oak Leaf Lake Unit has been managed as prairie since 1994, it’s moisture-retaining soils and annual precipitation allow woodland species such as sugar maple, green ash, orange jewelweed, white avens, and common elder to thrive.

While there are many naturally-occurring sources of woodland species seeds near the Oak Leaf Lake Unit, among them a small woodlot immediately to the east of Section C at the site (Figure A2), there are no close naturally-occurring sources of prairie species seeds. Kasota Prairie is 5 km away across the Minnesota River to the east of the site. It is highly unlikely that seeds from Kasota Prairie could buck the westerly winds and find their way to the Oak Leaf Lake Unit. Furthermore, many high-quality prairie species are adapted to dry upland soils; even if they were seeded at the site, conditions may not favor germination and/or seeding survival. Transplants may also fail to thrive. Prairie species adapted to dry uplands may be less able to compete with species adapted to mesic or wet soils. Environmental conditions at the Oak Leaf Lake may always preclude the establishment of the highest-quality upland prairie species.

My second null hypothesis, that species richness, as determined by the walk-through method, will not differ from species richness as determined by the random-sampling-in-quadrats method, is rejected. My alternative hypothesis, that the walk-through sampling method will generate greater species richness than the random-sampling-in-quadrats method, is supported with caution.

I found that a series of walk-throughs carried out during a full growing season will likely yield a more comprehensive plant species list because this method, in principal, allows an investigator the opportunity to locate “all” the species present at a site, including rare species and/or any species that are not listed because they occurred outside random sampling quadrats. That being said, if visits to a site are not carried out often enough, some species may flower between visits and go unnoticed. An investigator may not cover the entire area thoroughly, missing rare species. Basing a species list on a single season may also lead to omissions. For instance, extreme weather conditions may affect annual species (i.e. poor seed germination, poor seedling survival, small stature, failure to produce many or any flowers). Annual species that perform poorly during one year will likely produce fewer fruits and seeds, which could lead to a smaller population the following year. Herbaceous perennials may also be affected by extreme weather. The highest-quality indicators are sensitive to environmental conditions, and only thrive in sites that reliably provide those conditions. Sensitive perennial species may perform poorly (i.e., small stature, failure to produce many or any flowers). Small individuals that fail to flower may be overlooked using the walk-through method.

I accept my alternative hypothesis with caution because I did not test both sampling methods during the same year, which means that I cannot be absolutely certain that I would find the same species using the two methods. However, I located nearly twice as many species using the walk-through method in the same area that is mostly populated by herbaceous perennial species. Studies show that differences in weather (particularly drought) during different years do not substantially affect the presence of perennial species (Tilman and Haddi 1992).

Random-sampling-in-quadrats techniques are generally used to study "vegetation" on a site, i.e. "grassland," or "deciduous woodland." Strengths of this method include collecting abundance data that can be used to calculate diversity indices, like Shannon-Wiener and Simpson, and other quantitative data, including frequency, percent cover, and litter depth, which can provide statistical analyses and valuable insight into the overall characteristics and environmental conditions of the vegetation.

Vegetative studies tend to "simplify" vegetation into homogeneous sections, when in fact, much more heterogeneity often exists. Floristic studies can reveal heterogeneity but cannot assess abundance or distribution. Ideally, we should use floristic surveys hand-in-hand with random-sampling surveys to get a better understanding of the ecological quality of the grasslands. Tansley and Chipp (1926) wrote that "one can acquire a considerable floristic knowledge and yet know next to nothing about vegetation." The same can be said about vegetation: one can have knowledge of vegetation, but know little of the flora (Stohlgren 2007). Daubenmire also pointed out the need to have a complete species list for each vegetation type within a study area (Stohlgren 2007). A better understanding of flora and vegetation are needed to fully understand the dynamics of any site.

If one must choose one method or the other, two factors must be considered: 1) what is the primary goal of the study, and 2) what are the time and budget constraints? Sometimes more generalized information about the vegetation, and not specific species is needed, where other times require specific species identification. Limited funds and time often dictate how to best accomplish a study's goals in the allotted time or with the allotted money; logistics often do not allow for the ideal study situation.

Recommendations

I recommend continuing visits to the Oak Leaf Lake Unit to collect floristic data to further assess the quality of the site and to monitor the progress of the site's hoped for succession to longer-lived, higher-quality native perennials (Foster and Tilman 2000). Comparing monthly precipitation and temperature data for the study years with 30-year means (1981 to 2010) indicate that mid to late summer and fall were significantly drier and July was significantly hotter during both years. These data are in accord with observations that climate change is occurring in Minnesota. My baseline floristic data provide investigators with an opportunity to carry out long-term monitoring at the site. Changes in the composition of flora over time may provide insights into how climate change is affecting Minnesota's plant communities.

Prescribed burning, mowing, and herbicides should be considered to eliminate or reduce the spread of invasive species like wild parsnip and the infamously aggressive reed canary grass and Canada thistle so they do not further encroach and thereby reduce species richness and diversity at the site. Since the Oak Leaf Lake Unit is in the ecotone between the prairie and deciduous forest biomes, burning is vital because it kills tree and shrub seedlings. This will prevent inevitable succession, over time, to deciduous forest (Collins and Wallace 1990).

Site management should focus on ensuring diversity, especially of forbs, as it has been shown that grasses tend to overwhelm forb species in restored prairies (Baer et al. 2002; Camill et al. 2004). The addition of high-quality forb species, such *Phlox pilosa* (prairie phlox), *Heuchera richardsonii* (alumroot), and *Spirea alba* (meadowsweet), to name only a few, that thrive in mesic to wet-mesic soils, would increase the current diversity and inadequate FQI. Since the study site is isolated from naturally-occurring seed sources, it will be necessary to manually introduce these high-quality species. The three species noted above are located at Kasota Prairie and seeds from this local source could be collected and dispersed at the study site. Obtaining seeds from a nearby source not only keeps costs low, it also maintains local genetic integrity.

Many organizations and state and federal agencies are working together to maintain grasslands and connect grassland areas through corridors to facilitate the flow of plants and animals between areas. The biggest hurdles to prairie maintenance and restoration are political and economic constraints. Many government conservation programs intended to maintain or restore prairies are inadequate and difficult for landowners to navigate. Most programs are voluntary and the incentives are often not sufficient to entice landowners to have their land in prairie.

We must protect the few prairies that currently occur in Minnesota. More than 40 percent of Minnesota's CRP acres are expiring within a four-year period of this writing. Almost half of Minnesota's native prairies (114,000 of 235,076 acres) are not legally protected, which means the landowners can legally destroy them (MPPWG 2011). We have a responsibility to maintain and restore what we can by prolonging and simplifying conservation programs and increasing incentives for landowners to put or keep their land in prairie status. We should make an effort to improve the quality of prairies we currently have by increasing biodiversity through the introduction of native species and the control of invasive species.

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Appendix A

Figures A1-A2. Location of the Oak Leaf Lake Unit in Nicollet County, Minnesota. The site is located approximately 2 km west of Saint Peter. The coordinates for the study site are latitude 44.311050, longitude -94.015577.

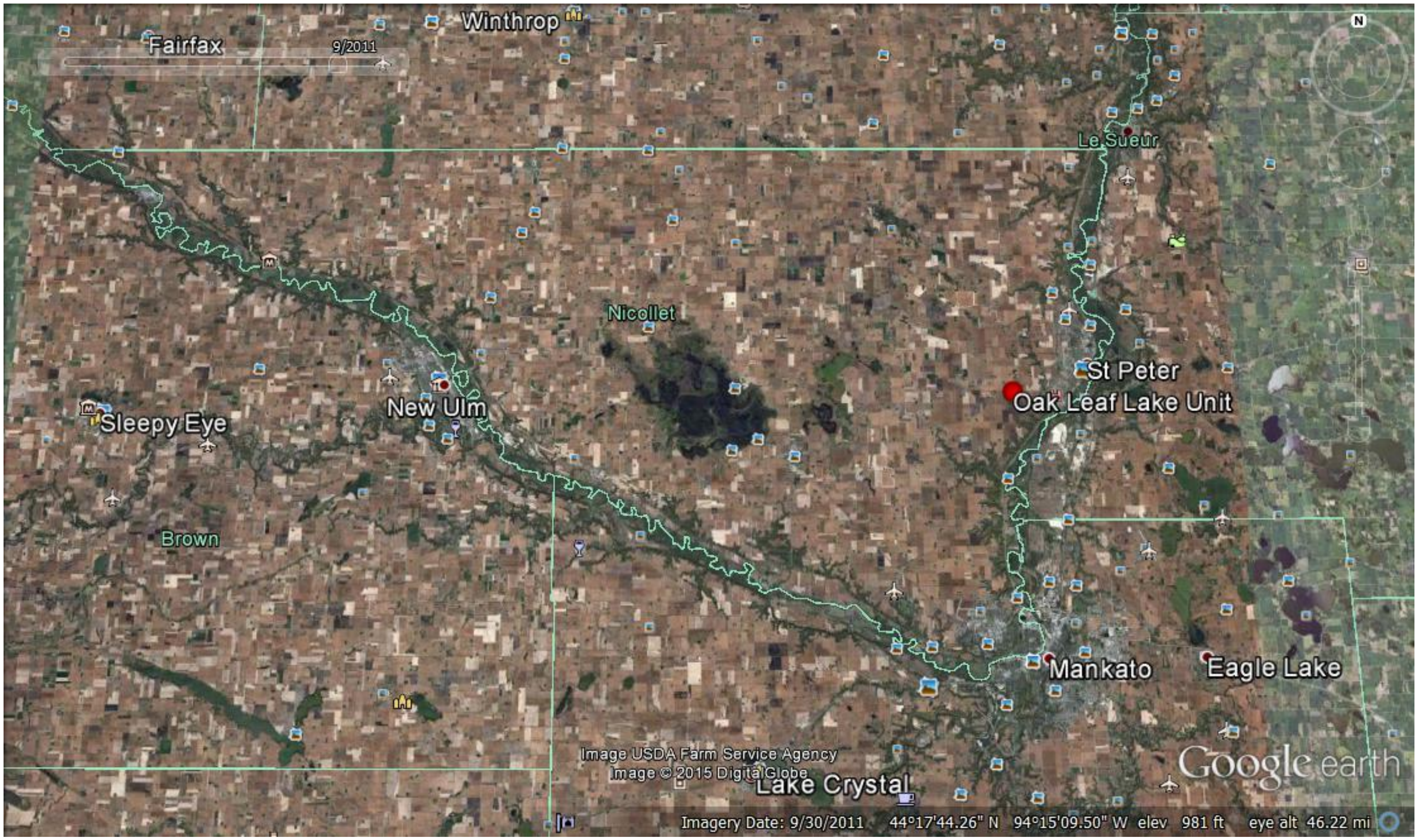

Figure A1. Location of the Oak Leaf Lake Unit in Nicollet County, Minnesota.

Figure A2. Map of the study site (within the white box) at the Oak Leaf Lake Unit and surrounding land.

Appendix B

Figure B1. Site map of the Oak Leaf Lake Unit showing study site divided into three sections, dependent upon soil type, land formations and other habitat characteristics. Section A is the most disturbed, with the driveway, parking area, and boat launch. Section B is upland grassland area. Section C contains the two wetland areas within the study site. Soil types are also shown. Soil type 109 is Cordova clay loam. Soil type 1075 is Klossner–Muskego soils, ponded. Soil type 978 is Cordova– Rolfe complex. Soil type 239 is Le Sueur clay loam.

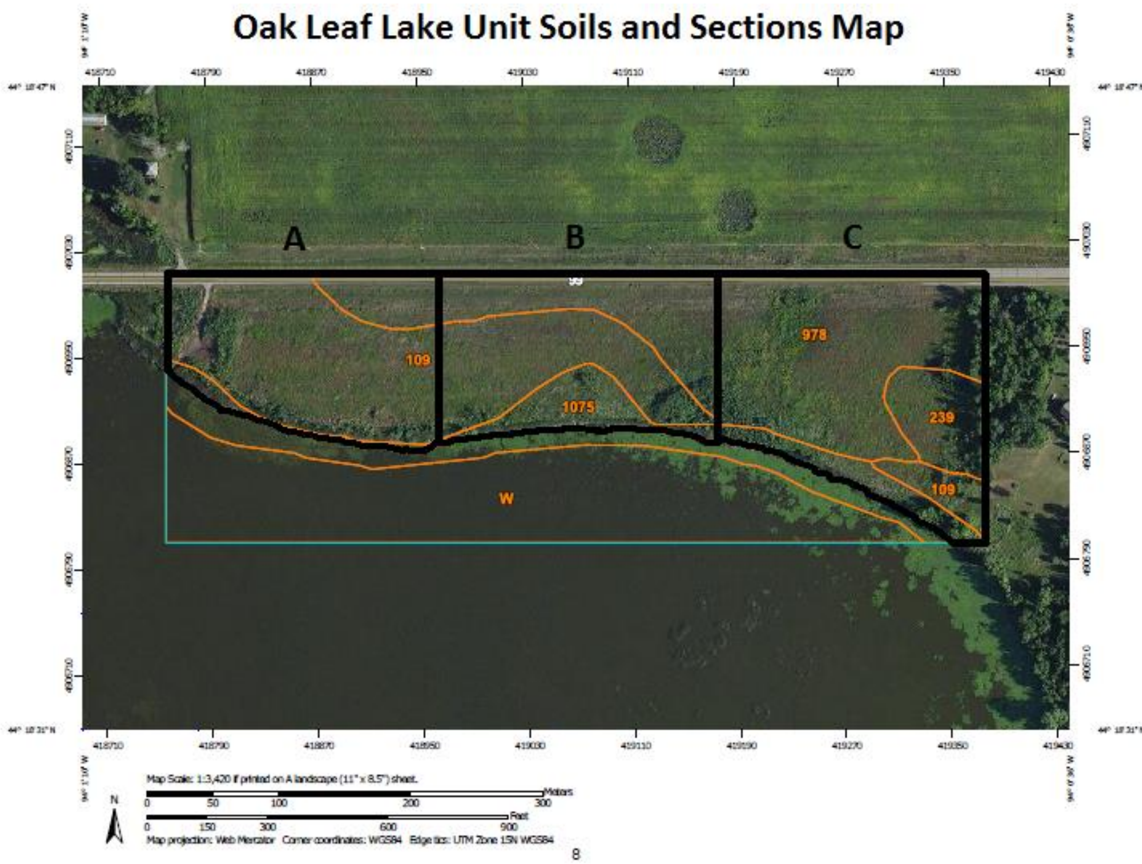

Figure B1. Site map of the Oak Leaf Lake Unit showing study site divided into three sections and by soil types.

Appendix C

Table C1. Soil types and descriptions found at the Oak Leaf Lake Unit as determined by the USDA. Column 1 lists soil type. Column 2 describes the elevation. Column 3 lists the mean annual precipitation and column 4 lists the mean annual air temperature. The frost free period is located in Column 5. Column 6 describes landforms. Column 7 gives slope percentage and Column 8 denotes drainage class. The capacity of the most limiting layer to transmit water is listed in Column 9. Column 10 is the depth of the water table in inches. Column 11 lists the frequency of flooding and Column 12 lists the frequency of ponding. The maximum calcium carbonate content of each soil type is listed in Column 13. Column 14 lists the available water capacity.

Table C1. Soil types and descriptions found at the Oak Leaf Lake Unit.

Soil Type and Location at Site	Elevation (m)	Mean Annual Precipitation (cm)	Mean Annual Air Temperature (° C)	Frost-free Period (Days)	Landform	Slope (%)	Drainage Class	Capacity of Most Limiting Layer to Transmit Water	Depth Water Table (cm)	Frequency of Flooding	Frequency of Ponding	Calcium Carbonate Maximum Content	Available Water Capacity
109 - Cordova clay loam (western half from driveway/parking lot to middle)	213 - 479	58 - 89	6 - 10	155 - 200	flats on moraines, swales on moraines	0 - 2	poorly drained	moderately low to moderately high (0.36 - 1.45 cm/hr)	about 15 - 46	none	none	0.2	high (about 25 cm)
239 - Le Sueur clay loam (middle of eastern side)	213 - 479	58 - 89	6 - 10	155 - 200	rises on moraines	1 - 3	somewhat poorly drained	moderately high to high (1.45 - 5.03 cm/hr)	about 46 - 76	none	none	0.3	high (about 27 cm)
978 - Cordova-Rolfe complex (northwest portion and middle of eastern half)	213 - 479	58 - 89	6 - 10	155 - 200	flats on moraines, swales on moraines	0 - 2	poorly drained	moderately low to moderately high (0.36 - 1.45 cm/hr)	about 15 - 46	none	none	0.2	high (about 26 cm)
1075 - Klossner-Muskego soils, ponded (shoreline)	213 - 479	58 - 89	6 - 10	155 - 200	depressions on moraines	0 - 1	very poorly drained	moderately low to high (0.36 - 5.03 cm/hr)	about 0	none	frequent	0.2	very high (about 50 cm)

Appendix D

Table D1. Plant species and collection data from the 2011-2012 Oak Leaf Lake Unit survey. Nomenclature per Gleason and Cronquist (1991). Origin status indicates whether the species is native (N), nonnative (NN), or unknown (U) (USDA 2012b). Section indicates the area in which the species were located on the site (Figure B1). 2011 Coll Date indicates the date when the voucher specimen was collected. Relocated in 2012 indicates whether the species was relocated using the random-sampling method. Bloom/Fruit Season indicates the time period in which species observed in 2011 were in bloom or fruit (I = June 3 – July 6, II = July 7 – August 13, and III = August 14 – September 23). All vouchers are housed at the Radichel Herbarium at Minnesota State University, Mankato.

Table D1. Plant survey data from the 2011-2012 Oak Leaf Lake Unit.

Family	Species	Common Name	Origin Status	Collection #	Section	2011 Coll Date	Relocated in 2012	Bloom/Fruit Season
Aceraceae (Maple)	*Acer saccharum* Marshall	sugar maple	N	116	A	9/23	X	III
Alismataceae (Water Plantain)	*Sagittaria* sp.	arrowhead	N	115	A	9/5		III
Apiaceae (Carrot)	*Cicuta maculata* L.	common water hemlock	N	42	C	7/1	X	I
Apiaceae (Carrot)	*Pastinaca sativa* L.	wild parsnip	NN	33	ABC	6/26	X	I
Apiaceae (Carrot)	*Zizia aurea* (L.) Koch	common golden alexander	N	4	ABC	6/13	X	I
Asclepiadaceae (Milkweed)	*Asclepias incarnata* L.	swamp milkweed	N	61	A	7/21		II
Asclepiadaceae (Milkweed)	*Asclepias syriaca* L.	common milkweed	N	96	B	8/25	X	III
Asclepiadaceae (Milkweed)	*Asclepias tuberosa* L.	butterfly-weed	N	55	A	7/7		II
Asteraceae (Sunflower)	*Achillea millefolium* L.	common yarrow	N	27	C	6/26		I
Asteraceae (Sunflower)	*Ambrosia artemisiifolia* L.	common ragweed	N	76	A	7/31	X	II
Asteraceae (Sunflower)	*Ambrosia trifida* L.	giant ragweed	N	86	A	8/6	X	II
Asteraceae (Sunflower)	*Anthemis cotula* L.	dogfennel, stinking chamomile	NN	58	A	7/13	X	II
Asteraceae (Sunflower)	*Arctium minus* Schk.	common burdock	NN	62	A	7/21	X	II
Asteraceae (Sunflower)	*Aster oolentangiense* Riddell	prairie heart-leaved aster	N	124	AB	9/23		III
Asteraceae (Sunflower)	*Aster sagittifolius* Wiild	arrow-leaved aster	N	123	A	9/23		III
Asteraceae (Sunflower)	*Aster* sp.	aster	U	113	ABC	9/5	X	III
Asteraceae (Sunflower)	*Aster* sp.	aster	U	102	C	8/25	X	III
Asteraceae (Sunflower)	*Cirsium arvense* Wimmer & Graebner var. *horridum*	Canada thistle	NN	38	ABC	7/1	X	I
Asteraceae (Sunflower)	*Cirsium vulgare* (Savi) Tenore	bull thistle	NN	92	A	8/14	X	III
Asteraceae (Sunflower)	*Conyza canadensis* (L.) Cronq.	horseweed	N	75	A	7/31		II

Family	Species	Common Name	Origin Status	Collection #	Section	2011 Coll Date	Relocated in 2012	Bloom/Fruit Season
Asteraceae (Sunflower)	*Erigeron strigosus* Muhl var. *strigosus*	rough fleabane	N	2	ABC	6/13		I
Asteraceae (Sunflower)	*Euthamia gymnospermoides* Greene	Great Plains flat-topped goldenrod	N	78	B	7/31		II
Asteraceae (Sunflower)	*Helenium autumnale* L.	common sneezeweed	N	68	ABC	7/31	X	II
Asteraceae (Sunflower)	*Helianthus grosseserratus* Martens	sawtooth sunflower	N	73	ABC	7/31	X	II
Asteraceae (Sunflower)	*Helianthus maximilianii* Schrader	Maximillian sunflower	N	98	ABC	8/25	X	III
Asteraceae (Sunflower)	*Heliopsis helianthoides* L.	common oxeye, smooth oxeye, false sunflower	N	29	ABC	6/26		I
Asteraceae (Sunflower)	*Lactuca canadensis* L.	tall lettuce	N	101	ABC	8/25	X	III
Asteraceae (Sunflower)	*Liatris pycnostachya* Michx.	prairie blazing star	N	87	B	8/6		II
Asteraceae (Sunflower)	*Ratibida pinnata* (Vent.) Barnhart	prairie, grey-headed, or globular coneflower	N	57	ABC	7/13	X	II
Asteraceae (Sunflower)	*Rudbeckia hirta* Farw var. *pulcherrima*	black-eyed Susan	N	39	ABC	7/1	X	I
Asteraceae (Sunflower)	*Solidago canadensis* L. var. *canadensis*	Canada goldenrod, common goldenrod	N	99	ABC	8/25	X	III
Asteraceae (Sunflower)	*Solidago canadensis* Rydb. var. *gilvocanescens*	Canada goldenrod, common goldenrod	N	112	ABC	9/5		III
Asteraceae (Sunflower)	*Solidago missouriensis* Nutt.	Missouri goldenrod	N	100	ABC	8/25		III
Asteraceae (Sunflower)	*Solidago nemoralis* Aiton.	gray goldenrod	N	111	B	9/5	X	III
Asteraceae (Sunflower)	*Solidago rigida* L.	stiff goldenrod	N	110	B	9/5	X	III
Asteraceae (Sunflower)	*Sonchus arvensis* L.	perennial sow-thistle	NN	47	ABC	7/7	X	II
Asteraceae (Sunflower)	*Taraxacum officinale* Weber ex. Wiggers	common dandelion	NN	11	A	6/19	X	I

Family	Species	Common Name	Origin Status	Collection #	Section	2011 Coll Date	Relocated in 2012	Bloom/Fruit Season
Asteraceae (Sunflower)	*Tragopogon dubius* Scop	fistulous goat's beard	NN	49	BC	7/7		II
Asteraceae (Sunflower)	*Vernonia fasciculata* Michx. var. *fasciculata*	smooth ironweed	N	90	A	8/6		II
Balsaminaceae (Touch-Me-Not)	*Impatiens capensis* Meerb.	orange forget-me-not, orange jewelweed	N	88	A	8/6		II
Brassicaceae (Mustard)	*Hesperis matronalis* L.	Dame's rocket, sweet rocket	NN	7	A	6/13		I
Brassicaceae (Mustard)	*Thlaspi arvense* L.	field pennycress	NN	6	A	6/13	X	I
Caprifoliaceae (Honeysuckle)	*Lonicera* sp.	honeysuckle	U	59	B	7/13		II
Caprifoliaceae (Honeysuckle)	*Sambucus canadensis* L.	common elder, American elderberry	N	84	ABC	8/6	X	II
Caryophyllaceae (Pink)	*Silene latifolia* Poiret	white campion, white cockle	NN	50	BC	7/7		II
Convolvulaceae (Morning Glory)	*Calystegia sepium* (L.) R. Br.	hedge bindweed	NN	54	A	7/7		II
Cupressaceae (Cypress)	*Juniperus virginiana* L.	Eastern red cedar	N	122	A	9/23	X	III
Cyperaceae (Sedge)	*Carex bebbii* (L.H. Bailey) Fern	Bebb's sedge	N	48	BC	7/7		II
Cyperaceae (Sedge)	*Carex rostrata* Stokes	beaked sedge	N	31	BC	6/26	X	I
Cyperaceae (Sedge)	*Carex vulpinoidea* Michx var. *vulpinoidea*	fox sedge	N	15	BC	6/19		I
Cyperaceae (Sedge)	*Cyperaceae* sp.	sedge	U	95	C	8/14		III
Cyperaceae (Sedge)	*Cyperus esculentus* L.	yellow nutsedge	NN	91	A	8/6		II
Cyperaceae (Sedge)	*Cyperus strigosus* L.	false nutsedge	N	93	C	8/14		III
Cyperaceae (Sedge)	*Eleocharis palustris* L.	common spikerush, creeping spike-rush	N	36	C	7/1		I
Cyperaceae (Sedge)	*Scirpus maritimus* L. (A. Nels.) Kuk var. *paludosus*	prairie bulrush, alkali bulrush	N	21	C	6/19	X	I
Cyperaceae (Sedge)	*Scirpus validus* Vahl	softstem bulrush, great bulrush, common bulrush	N	34	C	6/26	X	I
Fabaceae (Legume)	*Amorpha canescens* Pursh.	leadplant	N	97	C	8/25		III

Family	Species	Common Name	Origin Status	Collection #	Section	2011 Coll Date	Relocated in 2012	Bloom/Fruit Season
Fabaceae (Legume)	*Desmodium canadense* L. (DC)	Canadian tick-trefoil	N	53	A	7/7		II
Fabaceae (Legume)	*Medicago lupulina* L.	black medick	NN	46	A	7/1		I
Fabaceae (Legume)	*Melilotus alba* Medikus	white sweet clover	NN	40	BC	7/1		I
Fabaceae (Legume)	*Melilotus officinalis* (L.) Pallas	yellow sweet clover	NN	51	BC	7/7		II
Fabaceae (Legume)	*Trifolium hybridum* L.	alsike clover	NN	3	AB	6/13		I
Fabaceae (Legume)	*Trifolium pratense* L.	red clover	NN	70	A	7/31	X	II
Fabaceae (Legume)	*Trifolium repens* L.	white clover	NN	44	A	7/1		I
Fabaceae (Legume)	*Vicia americana* Muhl var. *americana*	American vetch, wild vetch	N	5	C	6/13	X	I
Fabaceae (Legume)	*Vicia cracca* L.	bird vetch	N	26	C	6/26		I
Iridaceae (Iris)	*Iris virginica* L. (Small) E. Anderson var. *shrevei*	southern blue flag iris	N	8	A	6/13		I
Lamiaceae (Mint)	*Agastache nepetoides* (L.) Kuntze	catnip, giant hyssop	N	80	B	8/6		II
Lamiaceae (Mint)	*Lamiaceae* sp.	mint	N	79	B	7/31		II
Lamiaceae (Mint)	*Leonurus cardiaca* L.	motherwort	NN	10	A	6/19		I
Lamiaceae (Mint)	*Monarda fistulosa* L.	wild bergamot	N	52	ABC	7/7	X	II
Liliaceae (Lily)	*Allium stellatum* Ker Gawler.	prairie onion	N	89	C	8/6		II
Moraceae (Mulberry)	*Morus alba* L.	white mulberry	NN	118	A	9/23	X	III
Nymphaeaceae (Water-Lily)	*Nymphaea odorata* Aiton	water lily	N	69	A	7/31		II
Oleaceae (Olive)	*Fraxinus pennsylvanica* Marshall	green ash	N	119	ABC	9/23	X	III
Oxalidaceae (Wood Sorrel)	*Oxalis stricta* L.	common yellow wood-sorrel	N	45	A	7/1	X	I
Plantaginaceae (Plantain)	*Plantago major* L.	common plantain	NN	43	A	7/1	X	I

Family	Species	Common Name	Origin Status	Collection #	Section	2011 Coll Date	Relocated in 2012	Bloom/Fruit Season
Poaceae (Grass)	*Andropogon gerardii* Vitman	big bluestem	N	64	ABC	7/21	X	II
Poaceae (Grass)	*Bromus commutatus* Schrader	hairy chess brome	NN	19	AB	6/19	X	I
Poaceae (Grass)	*Bromus inermis* Leysser	smooth brome	NN	18	ABC	6/19	X	I
Poaceae (Grass)	*Elytrigia repens* L.	quackgrass	NN	28	BC	6/26		I
Poaceae (Grass)	*Panicum virgatum* L.	switchgrass	N	106	ABC	9/5	X	III
Poaceae (Grass)	*Phalaris arundinacea* L.	reed canary grass	NN	14	ABC	6/19	X	I
Poaceae (Grass)	*Phleum pratense* L.	timothy	NN	16	AB	6/19		I
Poaceae (Grass)	*Poa compressa* L.	Canada bluegrass	NN	12	AB	6/19		I
Poaceae (Grass)	*Poa pratensis* L.	Kentucky bluegrass	NN	109	ABC	9/5	X	III
Poaceae (Grass)	*Poaceae* sp.	grass	U	37	B	7/1		I
Poaceae (Grass)	*Setaria glauca* (L.) P. Beauv.	yellow foxtail	NN	85	A	8/6		II
Poaceae (Grass)	*Sorghastrum nutans* (L.) Nash	Indian grass	N	107	ABC	9/5	X	III
Poaceae (Grass)	*Spartina pectinata* Link.	prairie cord-grass	N	83	C	8/6	X	II
Poaceae (Grass)	*Sphenopholis obtusata* (Torr) K.S. Erdman var. *major*	wedge grass	N	13	ABC	6/19	X	I
Polygonaceae (Smartweed)	*Polygonum amphibium* (L.) Michx. var. *emersum*	water smartweed	N	71	C	7/31	X	II
Polygonaceae (Smartweed)	*Rumex crispus* L.	curly dock	NN	9	A	6/19	X	I
Ranunculaceae (Buttercup)	*Thalictrum dasycarpum* Fischer & Ave-Lall.	purple meadow rue, tall meadow rue	N	23	C	6/26		I
Rosaceae (Rose)	*Geum canadense* Jacq.	white avens	N	32	A	6/26		I
Rosaceae (Rose)	*Pyrus malus* L.	crab apple	NN	120	A	9/23		III
Rosaceae (Rose)	*Rosa carolina L.*	Carolina rose	N	24	C	6/26	X	I
Rubiaceae (Madder)	*Galium boreale* L.	northern bedstraw	N	1	B	6/13		I

Family	Species	Common Name	Origin Status	Collection #	Section	2011 Coll Date	Relocated in 2012	Bloom/Fruit Season
Salicaceae (Willow)	*Populus alba* L.	white poplar	NN	117	A	9/23	X	III
Salicaceae (Willow)	*Salix exigua* Nutt.	sandbar willow	N	104	B	8/25	X	III
Scrophulariaceae (Figwort)	*Verbascum thapsus* L.	common mullein	NN	60	A	7/13		II
Scrophulariaceae (Figwort)	*Veronica longifolia* L.	long-leaved speedwell	N	63	A	7/21		II
Scrophulariaceae (Figwort)	*Veronicastrum virginicum* (L.) Farw.	Culver's root	N	67	B	7/31		II
Solanaceae (Nightshade)	*Physalis heterophylla* Nees.	clammy ground cherry	N	105	A	9/5	X	III
Solanaceae (Nightshade)	*Solanum dulcamara* L.	bittersweet nightshade	NN	25	C	6/26		I
Typhaceae (Cattail)	*Typha angustifolia* L.	narrow-leaved cattail	NN	35	ABC	6/26	X	I
Ulmaceae (Elm)	*Ulmus* sp.	elm	U	121	A	9/23	X	III
Urticaceae (Nettle)	*Urtica dioica* L.	stinging nettle	N	114	A	9/5	X	III
Verbenaceae (Vervain)	*Verbena hastata* L.	common or blue vervain	N	66	A	7/31	X	II
Verbenaceae (Vervain)	*Verbena stricta* Vent.	hoary vervain	N	94	A	8/14		III
Verbenaceae (Vervain)	*Verbena urticifolia* L.	white vervain	N	74	A	7/31		II
Vitaceae (Grape)	*Vitis riparia* Michx.	frost grape, river-bank grape	N	82	AB	8/6	X	II

Appendix E

The table included in Appendix E provides information for each species located at the study site, including duration and wetland code. Duration is the length of the species' life. Annuals perform their entire life cycle in one growing season. Biennials have a two-year cycle, with root, stems, and leaves produced in the first growing season and reproductive parts (flowers, fruit, and seeds) produced in the second growing season. Perennials live three or more years.

Wetland codes are assigned to species to determine their presence as an indicator of a wetland. Obligate wetland species almost always occur in wetlands. Facultative wetland species usually occur in wetlands, but may also occur in non-wetlands. Facultative species can occur either in wetlands or not. Facultative upland species usually occur in non-wetlands, but can be found in wetlands. Obligate upland species almost never occur in wetlands.

Table E1. Life history data, ecological requirements and indicator/weed status for plant species at the Oak Leaf Lake Unit. Nomenclature per Gleason and Cronquist (1991). Growth habits are indicated as follows: forb (F), grass (G), shrub (S), subshrub (SS), tree (T), and vine (V). Duration indicates if species are annual (A), biennial (B), or perennial (P). The habitat each species is most likely to be found in includes disturbed areas (DA), ditches (D), fields (F), lawns (L), marshes (Ma), meadow (Me), open places (OP), prairies (P), roadsides (R), shorelines (Sh), streambanks (St), swamps (Sw), thickets (T), waste places (WP), and woods (W). Wetland code are assigned as obligate wetland (OBL), facultative wetland (FACW), facultative (FAC), facultative upland (FACU), and obligate upland (UPL) (Ladd 2005; Lichvar et al. 2014). C-values range from 0-10 for native species, an asterisk indicates nonnative species, and none (N) indicates species are not listed (TNGPFQAP 2001; Ladd 2005). Indicator species are listed as Tier 1 (1) or Tier 2 (2) by the Minnesota County Biological Survey (Carlson 2010; MN DNR 2012a) or (C) if listed by Curtis (1955; 1971). Invasive species listed by the Minnesota County Biological Survey (Carlson 2010; MN DNR 2012a) Tier 1 (1) and Tier 2 (2). Weed status: MDA MN Prohibited Noxious Weeds (P) (2010, 2012), MDA MN Secondary Noxious Weeds (S) (2010, 2012), and “undesirable species” listed by Gleason and Cronquist (G) (1991) and University of Minnesota Extension (U) (2015a, 2015b, 2015c).

Table E1. Life history data, ecological requirements and indicator/weed status for plant species at the Oak Leaf Lake Unit.

Species	Growth Habit	Duration	Bloom Period/ Fruiting Season	Habitat	Wetland Code	C-value	Indicator Species	Invasive Species	Weed Status	Early-Successional	At Kasota Prairie
Acer saccharum Marshall	S, T	P	Ap, M Jun	W	FACU	10					
Achillea millefolium L.	F	P	Jun, Jul, Au, S, O	DA, F, R, WP	FACU	3					X
Agastache nepetoides (L.) Kuntze	F, SS	P	Au, S	W	FACU	8					
Allium stellatum Ker Gawler.	F	P	Jul, Au, S	P	UPL	7					X
Ambrosia artemisiifolia L.	F	A	Jul, Au, S, O	WP	FACU	0			G, U, S	X	X
Ambrosia trifida L.	F, SS	A	Jul, Au, S, O	WP	FAC	0			G, U, S	X	X
Amorpha canescens Pursh.	S, SS	P	Jun, Jul	P, W	UPL	9	1				X
Andropogon gerardii Vitman	G	P	Jul, Au	OP	FAC	5					X
Anthemis cotula L.	F	A	Jun, Jul, Au, S	F, WP	FACU	*			G	X	
Arctium minus Schk.	F	B	Jul, Au, S	R, WP	FACU	*		2	U, S	X	
Asclepias incarnata L.	F	P	Jun, Jul, Au	D, P, Sw	OBL	5					
Asclepias syriaca L.	F	P	Jun, Jul, Au	F, Me, R	FACU	0			S		X
Asclepias tuberosa L.	F	P	Jun, Jul, Au	P, W	UPL	9	2				X
Aster oolentangiense Riddell	F, SS	P	Au, S, O	P, W	UPL	10	2				
Aster sagittifolius Wiild	F	P	Jul, Au, S, O	OP, St, W	NL	8					
Aster sp.	P	P	Unknown	U	U	N					
Aster sp.	P	P	Unknown	U	U	N					
Bromus commutatus Schrader	G	A	M, Jun, Jul	DA	NL	N				X	
Bromus inermis Leysser	G	P	Jun, Jul	DA, D, F, OP, P, R	FACU	*		1			X
Calystegia sepium (L.) R. Br.	F, V	P	Jun, Jul, Au	DA, Sh, T	FAC	0		2			X

Species	Growth Habit	Duration	Bloom Period/ Fruiting Season	Habitat	Wetland Code	C-value	Indicator Species	Invasive Species	Weed Status	Early-Successional	At Kasota Prairie
Carex bebbii (L.H. Bailey) Fern	G	P	Jun, Jul	Me, Sh	OBL	8					
Carex rostrata Stokes	G	P	Jun, Jul, Au	Sh	OBL	8					
Carex vulpinoidea Michx var. *vulpinoidea*	G	P	M, Jun	Ma, Sh, Sw	FACW	2					
Cicuta maculata L.	F	P	Jun, Jul, Au	D, Ma, Sw	OBL	4	C				
Cirsium arvense Wimmer & Graebner var. *horridum*	F	P	Jul, Au	F, WP	FACU	*		1	G, U, P		X
Cirsium vulgare (Savi) Tenore	F	B	Jun, Jul, Au, S, O	F, R, P, WP	FACU	*		1	G, U, P		
Conyza canadensis (L.) Cronq.	F	A	Jul, Au, S, O	F, WP	NL	0			G	X	X
Cyperaceae sp.	G	P	Unknown	U	U	N					
Cyperus esculentus L.	G	P	Jul, Au, S	Ma, Sh, Sw	FACW	0			G, U, S		
Cyperus strigosus L.	G	P	Au, S, O	F, Sh, Sw	FACW	3					
Desmodium canadense L. (DC)	F	P	Jul, Au	St, T	FACU	6	C				
Eleocharis palustris L.	G	P	M, Jun, Jul, Au	Ma, Sh, Sw	OBL	N					
Elytrigia repens L.	G	P	Jun, Jul	DA	NL	N		1	G, U, S		
Erigeron strigosus Muhl var. *strigosus*	F	A, B	Jun, Jul, Au, S	DA	FACU	3			G	X	X
Euthamia gymnospermoides Greene	F	P	Jul, Au, S	OP	FACW	5					
Fraxinus pennsylvanica Marshall	T	P	M, Jun	W	FACW	5					
Galium boreale L.	F, SS	P	Jun, Jul	Me, St, W	FAC	4	C				X
Geum canadense Jacq.	F	P	M, Jun	W	FAC	4					
Helenium autumnale L.	F	P	Jul, Au, S, O	Sh, St	FACW	4	1				

Species	Growth Habit	Duration	Bloom Period/ Fruiting Season	Habitat	Wetland Code	C-value	Indicator Species	Invasive Species	Weed Status	Early-Successional	At Kasota Prairie
Helianthus grosseserratus Martens	F	P	Au, S, O	F, Me, P	FACW	7	C				X
Helianthus maximilianii Schrader	F	P	Jul, Au, S, O	P, WP	UPL	5					
Heliopsis helianthoides L.	F	P	Jul, Au, S	P, WP, W	FACU	5					X
Hesperis matronalis L.	F	B, P	M, Jun	F, W	FACU	*					
Impatiens capensis Meerb.	F	A	Jun, Jul, Au, S	D, St, W	FACW	4				X	
Iris virginica L. (Small) E. Anderson var. *shrevei*	F	P	M, Jun, Jul	D, Ma, Me, S	OBL	N					
Juniperus virginiana L.	T	P	M, Jun, Jul	DA, Me, OP, P, W	FACU	0					X
Lactuca canadensis L.	F	A, B	Jul, Au, S	F, WP, W	FACU	6				X	X
Lamiaceae sp.	U	U	Unknown	U	U	N					
Leonurus cardiaca L.	F	P	Jun, Jul, Au, S	DA, R, WP	NL	*			G		X
Liatris pycnostachya Michx.	F	P	Jul, Au, S	P, W	FAC	8	1				
Lonicera sp.	S	P	Unknown	U	U	N					
Medicago lupulina L.	F	A, B	M, Jun, Jul, Au, S	P, R	FACU	*		2	G, U	X	X
Melilotus alba Medikus	F	A, B	Jun, Jul, Au, S, O	R, WP	NL	*		1	G	X	X
Melilotus officinalis (L.) Pallas	F	A, B	Jun, Jul, Au, S	WP	FACU	*		1	G	X	X
Monarda fistulosa L.	F, SS	P	Jun, Jul, Au, S	P, T, W	FACU	5					X
Morus alba L.	S, T	P	M, Jun	DA, F, R, W	FAC	*		2			
Nymphaea odorata Aiton	F	P	Jun, Jul, Au, S	Sh	OBL	9					
Oxalis stricta L.	F	P	Jun, Jul, Au, S, O	F, R, WP	FACU	0			G, U		X

Species	Growth Habit	Duration	Bloom Period/ Fruiting Season	Habitat	Wetland Code	C-value	Indicator Species	Invasive Species	Weed Status	Early-Successional	At Kasota Prairie
Panicum virgatum L.	G	P	Jun, Jul, Au	Ma, P, Sh, W	FAC	5					X
Pastinaca sativa L.	F	B	Jun, Jul	F, R, WP	NL	*		1	G, U	X	
Phalaris arundinacea L.	G	P	Jun, Jul	Ma, Sh, St	FACW	0		1	U		X
Phleum pratense L.	G	P	Jun, Jul, Au	DA, F, P	FACU	*		1			X
Physalis heterophylla Nees.	F	P	Jun, Jul, Au, S	P, W	UPL	5					X
Plantago major L.	F	P	Jun, Jul, Au, S, O	L, R, WP	FAC	*		2	U	X	
Poa compressa L.	G	P	Jun, Jul	OP, R	FACU	*		1			X
Poa pratensis L.	G	P	Jun, Jul	DA, D, L, P, R, WP	FAC	*		1			X
Poaceae sp.	G	U	Unknown	U	U	N					
Polygonum amphibium (L.) Michx. var. *emersum*	F	P	Jul, Au, S	Ma, Sh, St, Sw	OBL	0					
Populus alba L.	T	P	Ap, M	DA, F, Me	NL	*					
Pyrus malus L.	S, T	P	M, Jun	DA, Me, R	NL	N					
Ratibida pinnata (Vent.) Barnhart	F	P	Jun, Jul, Au	F, P, W	UPL	6	C				
Rosa carolina L.	SS	P	M, Jun	DA, F, Me, OP, P, R	FAC	N					
Rudbeckia hirta Farw var. *pulcherrima*	F	B, P	Jun, Jul, Au, S, O	Me, P, R	FACU	5	C			X	X
Rumex crispus L.	F	P	Jun, Jul	R, WG, F	FAC	*		2	G, S	X	
Sagittaria sp.	P	P	Unknown	U	U	N					
Salix exigua Nutt.	S, T	P	Ap, M	Ma, Sh, Sw	OBL	3					

Species	Growth Habit	Duration	Bloom Period/ Fruiting Season	Habitat	Wetland Code	C-value	Indicator Species	Invasive Species	Weed Status	Early-Successional	At Kasota Prairie
Sambucus canadensis L.	S, T	P	Jul, Au	F, R, W	FACU	4					
Scirpus maritimus L. (A. Nels.) Kuk var. *paludosus*	G	P	Jun, Jul, Au, S	Ma, Sh, Sw	NL	4					
Scirpus validus Vahl	G	P	Jun, Jul, Au	Ma, Sh, Sw	OBL	3					
Setaria glauca (L.) P. Beauv.	G	P	M, Jun, Jul, Au, S	DA, F, WP	FAC	*		2	G, U		
Silene latifolia Poiret	F	A, B, P	M, Jun, Jul, Au, S	F, R, WP	NL	N			G	X	
Solanum dulcamara L.	F, SS, V	P	Jun, Jul, Au, S	OP, T, W	FAC	*					
Solidago canadensis L. var. *canadensis*	F	P	Jul, Au, S, O	OP, W	FACU	1					X
Solidago canadensis Rydb. var. *gilvocanescens*	F	P	Jul, Au, S, O	OP, W	FACU	1					X
Solidago missouriensis Nutt.	F	P	Jul, Au, S	OP, P, W	UPL	5	C				X
Solidago nemoralis Aiton.	F	P	Au, S, O	OP, W	UPL	6	C				X
Solidago rigida L.	F	P	Au, S, O	OP, P	FACU	4					X
Sonchus arvensis L.	F	P	Jul, Au, S, O	DA, F, R	FACU	*		1	G, U, P		
Sorghastrum nutans (L.) Nash	G	P	Au, S	F, P, W	FACU	6	2				X
Spartina pectinata Link.	G	P	Jun, Jul	Ma, Sh	FACW	5	C				X
Sphenopholis obtusata (Torr) K.S. Erdman var. *major*	G	P	M, Jun	Me, Sh, St	FAC	7					
Taraxacum officinale Weber ex. Wiggers	F	P	Ap, M, Jun, Jul, Au, S, O	DA, L	FACU	*		2	G, U	X	X
Thalictrum dasycarpum Fischer & Ave-Lall.	F	P	Jun, Jul	Me, Sh, St	FACW	7	2, C				X
Thlaspi arvense L.	F	A	Ap, M, Jun	WP	FACU	*				X	
Tragopogon dubius Scop	F	B	M, Jun, Jul	OP, R	NL	*				X	X

Species	Growth Habit	Duration	Bloom Period/ Fruiting Season	Habitat	Wetland Code	C-value	Indicator Species	Invasive Species	Weed Status	Early-Successional	At Kasota Prairie
Trifolium hybridum L.	F	P	Jun, Jul, Au, S	Me, P, R	FACU	*		1		X	
Trifolium pratense L.	F	P	M, Jun, Jul, Au	F, R	FACU	*		1		X	X
Trifolium repens L.	F	P	Jun, Jul, Au, S	L, R	FACU	*		1	U		X
Typha angustifolia L.	F	P	M, Jun	Ma	OBL	*					
Ulmus sp.	T	P	Unknown	U	U	N					X
Urtica dioica L.	F	P	Jun, Jul, Au, S	DA, W	FACW	0			U		
Verbascum thapsus L.	F	B	Jun, Jul, Au, S	DA	UPL	*		2		X	X
Verbena hastata L.	F	P	Jun, Jul, Au, S, O	F, Me, P, Sw	FACW	5					X
Verbena stricta Vent.	F	P	Jun, Jul, Au, S	F, OP, P, R	UPL	2					X
Verbena urticifolia L.	F	P	Jun, Jul, Au, S, O	F, Me, T, WP	FAC	3					
Vernonia fasciculata Michx. var. *fasciculata*	F	P	Jul, Au, S	P, Ma	FACW	3					X
Veronica longifolia L.	F	P	Jun, Jul, Au	F, R, WP	NL	*					
Veronicastrum virginicum (L.) Farw.	F	P	Jun, Jul, Au	P, W	FAC	10	2, C				X
Vicia americana Muhl var. *americana*	F, V	P	M, Jun, Jul	W	FACU	3					X
Vicia cracca L.	F, V	P	Jun, Jul, Au	F, Me, R	NL	N					
Vitis riparia Michx.	V	P	M, Jun	R, T, W	FACW	3			U		X
Zizia aurea (L.) Koch	F	P	M, Jun	F, Me	FAC	8	1, C				

Appendix F

Figure F1-F3. Species area curves for "early-" (**I** = June 3 – July 6), "mid-" (**II** = July 7 – August 13), and "late-blooming/fruiting" (**III** = August 14 – September 23) periods of the random sampling method.

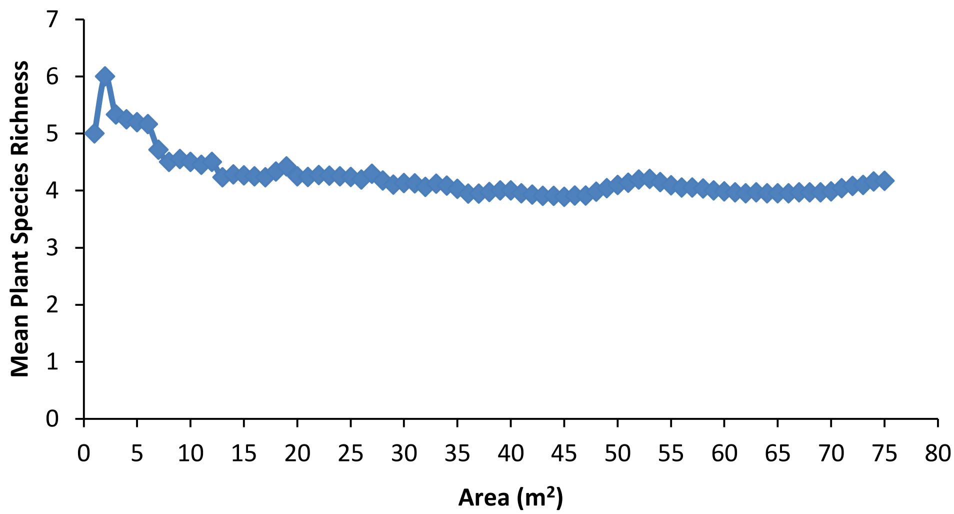

Figure F1. Species area curve for Period I (the early-blooming/fruiting period) of the random-sampling method.

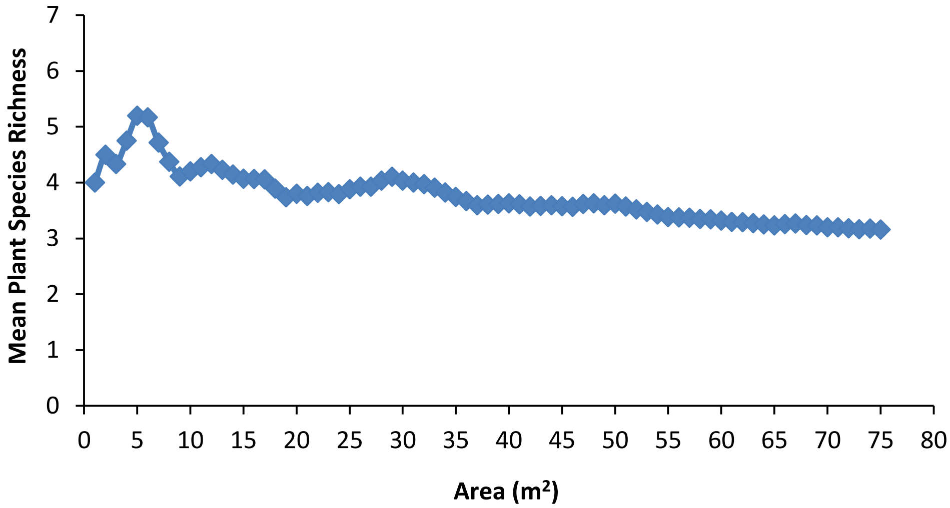

Figure F2. Species area curve for Period II (the mid-blooming/fruiting period) of the random-sampling method.

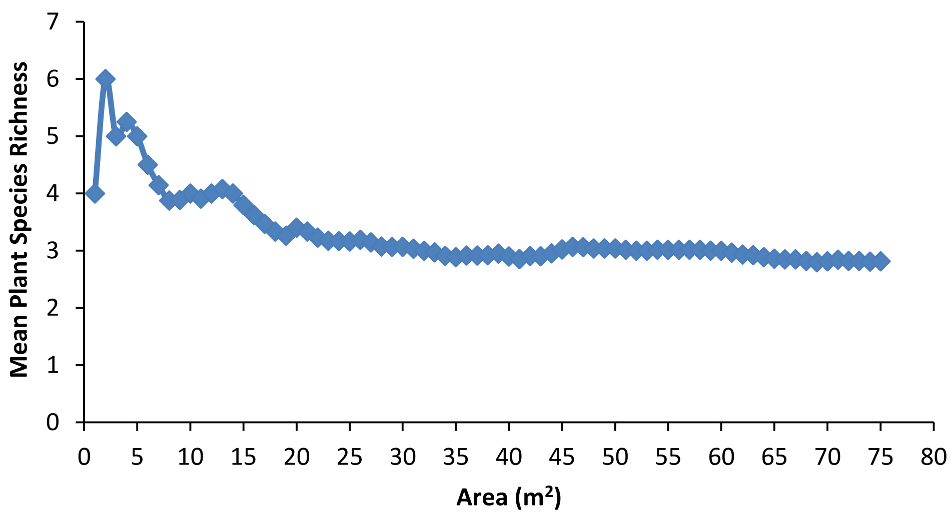

Figure F3. Species area curve for Period III (the late-blooming/fruiting period) of the random-sampling method.

Appendix G

Table G1. Selected early-successional, nonnative, invasive, noxious (P = State Prohibited Noxious, S = State Secondary Noxious), and high-quality indicator (T-1 = Tier 1, T-2 = Tier 2, C = *sensu* Curtis [1955; 1971]) species found at the Oak Leaf Lake Unit, the section(s) within which they were located and their wetland codes, if known (OBL = obligate wetland, FACW = facultative wetland, FAC = facultative, FACU = facultative upland, and UPL = obligate upland [Ladd 2005; Lichvar et al. 2014]).

Species	Early-successional	Section(s)	Wetland code	Nonnative	Invasive	Noxious	High-quality indicator
alexander, common golden		A B C	FAC				T-1, C
aster, prairie-heart-leaved		A B	UPL				T-2
bedstraw, northern		B	FAC				C
black-eyed Susan	x	A B C	FACU				C
blazing star, prairie		B	FAC				T-1
burdock, common	x	A	FACU	x	x	S	
campion, white	x	B C		x			
clover, alsike	x	A B	FACU	x	x		
clover, red	x	A	FACU	x	x		
clover, white		A	FACU	x	x		
clover, sweet white	x	B C		x	x		
clover, sweet yellow	x	B C	FACU	x	x		
coneflower, prairie		A B C	UPL				C
Culver's root		B	FAC				T-2, C
dandelion, common	x	A	FACU	x	x		
dock, curly	x	A	FAC	x	x	S	
dogfennel	x	A	FACU	x			
fleabane, rough	x	A B C	FACU				
goat's beard, fistulous	x	B C		x			
goldenrod, gray		B	UPL				C
goldenrod, Missouri		A B C	UPL				C
grass, Canada blue-		A B	FACU	x	x		
grass, hairy chess	x	A B		x			
grass, Indian		A B C	FACU				T-2
grass, Kentucky blue-		A B C	FAC	x	x		

Species	Early-successional	Section(s)	Wetland code	Nonnative	Invasive	Noxious	High-quality indicator
grass, prairie cord-		C	FACW				C
grass, quack-		B C		x	x	S	
grass, reed canary		A B C	FACW	x	x		
grass, smooth brome		A B C	FACU	x	x		
grass, timothy		A B	FACU	x	x		
grass, yellow foxtail		A	FAC	x	x		
hedge bindweed		A	FAC	x	x		
horseweed	x	A					
jewelweed, orange	x	A	FACW				
leadplant		C	UPL				T-1
lettuce, tall	x	A B C	FACU				
meadow rue, tall		C	FACW				T-2, C
medick, black	x	A	FACU	x	x		
milkweed, butterfly-		A	UPL				2
milkweed, common		B	FACU			S	
mulberry, white		A	FAC	x	x		
mullein, common	x	A	UPL	x	x		
nutsedge, yellow		A	FACW	x		S	
parsnip, wild	x	A B C		x	x		
pennycress, field	x	A	FACU	x			
plantain, common	x	A	FAC	x	x		
ragweed, common	x	A	FACU			S	
ragweed, giant	x	A	FAC			S	
sneezeweed, common		A B C	FACW				T-1
sowthistle, perennial		A B C	FACU	x	x	P	
sunflower, sawtooth		A B C	FACW				C
thistle, bull		A	FACU	x	x	P	
thistle, Canada		A B C	FACU	x	x	P	
tick-trefoil, Canadian		A	FACU				C
water hemlock, common		C	OBL				C

Appendix H

Table H1. Indices for analyses of data collected in this study, along with their calculations and purpose.

Index	Calculation	Purpose
Species richness	number of species located within a specified area	required to measure species diversity
Species abundance	estimate of number of individuals of each species present	required to measure species diversity
Species diversity	species richness and species abundance	measure diversity within a community
Shannon-Wiener Index	$H = \sum P_i \ln P_i$	measure of species diversity
Simpson's Index of Diversity	$D = 1 - \sum p_i^2$	measure of species diversity
Jaccard's Coefficient	$C_j = a/(a+b+c)$	assess similarity between members of two data sets
Frequency	$f_i = j_i/k$	measure uniformity of distribution of plant species in an area
Percent cover	*([number of quadrats containing the cover class]*[midpoint of the cover class])/ total number of quadrats sampled*	% of ground surface within a specified area covered by an entity
Species area curve	area (m^2) plotted on x-axis, mean plant species richness plotted on y-axis	determine when sufficient number of samples have been collected
Coefficient of Conservatism (C-value)	values range from 0 - 10	ranks plants on their “conservatism”, ability to tolerate disturbances and likelihood to be found in undisturbed habitats
Mean C-value	Mean-C = (∑C)/N	assess site quality, summarize overall floristic ranking
Floristic Quality Index	FQI = Mean-C*√N	asses site quality, overall floristic ranking with weighted species richness

Appendix I

Figures I1-I6. Photographs of the study site at various sampling times.

Figure I1. Photograph of the signage at the Oak Leaf Lake Unit taken on June 19, 2011. The photograph is facing south with Oak Leaf Lake in the background.

Figure I2. Photograph of the Oak Leaf Lake Unit taken on June 26, 2011. The photograph is facing east overlooking Section A with the driveway, parking lot, and boat access behind to the west and Oak Leaf Lake to the south (right) and Minnesota State Highway 99 to the north (left).

Figure I3. Photograph of the Oak Leaf Lake Unit taken on August 6, 2011. The photograph is facing southeast overlooking Sections A and B and Oak Leaf Lake.

Figure I4. Photograph of the Oak Leaf Lake Unit taken on August 6, 2011. The photograph is facing east overlooking Sections A and B and Oak Leaf Lake.

Figure I5. Photograph of the Oak Leaf Lake Unit taken on August 14, 2011. The photograph is facing east overlooking Section B with Oak Leaf Lake to the south (right) and Minnesota State Highway 99 to the north (left).

Figure I6. Photograph of the Oak Leaf Lake Unit taken on September 23, 2011. The photograph is facing east overlooking Section A with the driveway, parking lot, and boat access behind to the west and Oak Leaf Lake to the south (right) and Minnesota State Highway 99 to the north (left).