

**Land Use and Climate Influence Marshes in the Northern Prairie and Parkland Region**

by

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## **Author's Declaration**

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

## **Abstract**

I evaluated the association between waterbird communities and agricultural activity at 48 non-permanent wetlands, and waterbird response to inter-annual climate variation at 24 non-permanent wetlands. I found six distinct assemblages of waterbirds, each with indicator species reflective of disturbance, landscape (500 m), and site level variables. The 6 assemblages can be predicted using a combination of landscape (forest cover, water and wetlands, and pasture) and site level variables (robust emergent vegetation, woody vegetation and maximum water depth), but differences between natural regions account for more variation than non-natural cover. Results indicate waterbird community composition is undergoing a shift from multiple distinct assemblages that have specialist and sensitive species to assemblages that are made up of common, generalist species, due to increased agriculture in the landscape. I also found that waterbird community composition is sensitive to variation in climate. Between 2014 and 2015, waterbird community composition differed with natural region, disturbance level and wetland class, but the only significant interaction occurred between natural region and year. It appears that the types of changes in composition provoked by inter-annual variation in climate are largely orthogonal to changes that occur in response to agricultural disturbance. These results suggest certain aspects of waterbird community composition can be effective at indicating ecological condition in the Parkland and Grassland natural regions, while being relatively insensitive to inter-annual climate variation, especially if tools are tailored to natural region.

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## **List of Abbreviations**

Arctic Oscillation (AO)

Classification and Regression Trees (CART)

El Nino Southern Oscillation (ENSO)

Index of Biotic Integrity (IBI)

Non-metric Multidimensional Scaling (NMS)

Northern Prairie and Parkland Region (NP&PR)

Pacific Decadal Oscillation (PDO)

Prairie Pothole Region (PPR)

Sea-surface Temperature (SST)

Shannon Diversity ( $H'$ )

## **1. General Introduction and Thesis Overview**

### **1.1. Northern Prairie Pothole Wetlands: History**

The Northern Prairie and Parkland Region (NP&PR) encompasses about 1,197,000 km<sup>2</sup>, covering portions of Canada and the United States (Beyersbergen et al. 2004, Wrubleski and Ross 2011). Within Canada, the NP&PR represents more than 80% of western Canada (Batt et al. 1989) and spans four ecoregions: the Boreal Transition Zone, Prairie Pothole, Aspen Parklands, and Northern Grasslands (Ecological Stratification Working Group 1996, Beyersbergen et al. 2004).

Pleistocene glaciers shaped the NP&PR landscape and deposited glacial till resulting in a hummocky profile dotted with shallow wetland basins (Batt et al. 1989). Glacial till deposits have very low permeability allowing precipitation to accumulate (Goldhaber et al. 2014). The till underlying the NP&PR is characterized by reactive minerals such as feldspar and quartz, dolomite and calcite, and pyrite from the Canadian Shield, southern Canadian Paleozoic carbonates and late Cretaceous marine shale. The composition of the underlying till and the weathering that occurs acts to buffer the chemical composition of water in the NP&PR wetlands (Goldhaber et al. 2014). The deposits contribute to the extreme productivity of the wetlands because they are a source of rich mineral nutrients that remain within the wetlands (van Der Kamp and Hayashi 2009).

### **1.2. Hydrology**

These shallow glaciated basins with low permeability lend themselves to non-permanent marshes which are classified under the Stewart and Kantrud (1970) and the new Alberta Wetland

(2015) classification systems as class I (ephemeral), class II (temporary), class III (seasonal) and class IV (semi-permanent) marshes. Wetlands have a relatively fixed area that is defined by hydric soil and associated hydrophytes, but the pond or open water area changes as a result of hydrologic input (van Der Kamp and Hayashi 2009). Wetlands that have permanent open water zones fall under the classification systems as class V or permanent ponds and lakes (Stewart and Kantrud 1970, Alberta Environment and Sustainable Resource Development 2015). Non-permanent marshes naturally fluctuate between inundated and dry periods; this unique cycle is characteristic of the wetlands within the NP&PR and results in abundant plant and animal diversity (Sharitz and Batzer 1999, Niemuth et al. 2014). These wetlands play a vital role in the landscape; they provide habitat for a diverse set of flora and fauna, groundwater recharge during drought, flood control during deluge, and they act as carbon sinks (Mitsch 2007).

Typically in Alberta, these systems are filled by snowmelt and early spring rain resulting in standing water from spring to mid-summer (Swanson and Duebbert 1989, van Der Kamp and Hayashi 2009). These wetlands are generally hydrologically isolated and internally drained, but ecologically connected as wetland complexes (Johnson et al. 2010). If surface water connections with surrounding wetlands are present, it is through a “fill and spill” mechanism (Euliss et al. 2004, van Der Kamp and Hayashi 2009). Because they are filled with snowmelt and have available open water where more permanent wetlands will still be thawing, non-permanent marshes promote early spring biological activity (Johnson et al. 2010, Niemuth et al. 2014).

### 1.3. Climate

The NP&PR climate is influenced by the complex interactions of three air masses: Maritime Polar, Maritime Tropical and Continental Polar (Natural Regions Committee 2006, Millett et al. 2009). Normal climatic fluctuations and weather extremes such as high summer temperatures and low humidity (Millett et al. 2009) drive the cyclic hydrology of the non-permanent marshes in the NP&PR. A strong precipitation gradient occurs in the NP&PR with areas situated to the north and west receiving less precipitation (300 mm/year) and evaporation rates greatly exceeding precipitation compared to areas to the south and east, which can receive up to 900 mm/year (Millett et al. 2009, Ballard et al. 2014). The precipitation gradient is somewhat moderated by a north-south temperature gradient that causes cooler temperatures and shorter growing seasons in the north NP&PR (Millett et al. 2009, Bartzen et al. 2010). Nested within the north-western portion of the NP&PR where my research is focused, precipitation is low and the precipitation gradient runs opposite to the larger regional gradient: the Southern part of my study region (Grassland) receives markedly less precipitation than the Northern half (Parkland). 1981-2010 mean annual temperature normals are shown in Appendix 1 for the Grassland and Parkland.

Atmospheric circulations such as El Nino Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) also have significant influence on the surface temperature and precipitation in Alberta (Coulibaly 2006, Lapp and Kienzle 2013, Jiang et al. 2014). Sea surface temperature (SST) variability caused by the PDO drives winter precipitation in the Pacific Northwest and is particularly evident in Southern Alberta (Lapp and Kienzle 2013). PDO is relatively low frequency; it shifts from a warm (positive) to cool (negative) phase every 20 to 35

years. ENSO operates at a higher frequency shifting every 2 to 7 years. During the warm phase of ENSO, Alberta can generally expect to be dry (Jiang et al. 2014). According to the National Oceanic and Atmospheric Association (2015), 2012-2014 were part of a normal phase in terms of SST and subsequent ENSO, but as of 2015 the SST shifted to above normal temperatures indicating that a ENSO warm phase has begun. The relationship between large-scale atmospheric circulations are still poorly understood due to their inherent instability (Jiang et al. 2014) but three dominant oscillations (2 to 3 year, 3 to 6 year and 6 to 12 year) have been identified that influence seasonal precipitation in Canada (Coulibaly 2006). Consequently, the hydrology within NP&PR is highly variable between years and additional predicted variability as a result of anthropogenic climate change will affect the species composition, permanence class and primary productivity of wetlands in the region (Johnson et al. 2005).

Climate models predict increasing temperatures, ranging from 2-4 degrees Celsius by 2100 (Cambridge University and Stocker 2014), with very little increase in precipitation during times when evapotranspiration is high. Increasing temperatures may cause an increase in the frequency of droughts (Russell 1990, Schindler and Donahue 2006); the resulting shrinkage in water budgets will reduce wetland area and affect the capacity of remaining wetlands to provide ecosystem goods and services (Johnson et al. 2010). It is predicted that overall there will be many fewer wetlands within the landscape and a significant reduction in waterbird breeding (Millett et al. 2009, Steen et al. 2014) as a consequence of climate change.

Although climate change is predicted to significantly impact wetlands in the NP&PR, the typical shallow water and relatively short hydroperiods that are characteristic of non-permanent marshes may be an advantage in the face of anticipated climate change. This is because wetlands

with long hydroperiods (i.e. Class V) will see a greater change in hydroperiod than wetlands with shorter hydroperiods (i.e. Class I-IV). Because non-permanent marshes are usually already dry in the hottest part of the summer when climate warming will be most severe, evaporation and transpiration rates will be less affected than in permanent wetlands (Johnson et al. 2010). Thus, non-permanent wetlands may offer enhanced resilience of the landscape to climate change. Consequently, research needs to focus not only on permanent wetlands but also on the smaller, often overlooked non-permanent marshes.

#### **1.4. Waterbirds in Non-permanent Marshes**

Historically, the most recognized and reported value ascribed to wetlands is their role as waterfowl habitat (Valk 1989, Amezaga et al. 2002, Mitsch 2007, Wrubleski and Ross 2011), and wetlands of the NP&PR are considered the most important breeding area for waterfowl in North America (Valk 1989, Beyersbergen et al. 2004, Wrubleski and Ross 2011). While water is present, non-permanent marshes are a valuable habitat to many, including waterfowl, shorebirds (Hands et al. 1991) and wetland-dependent songbirds (waterbirds herein) and their benthic macroinvertebrate food (invertebrates) (Silver and Vamosi 2012). The early thawing and filling with snowmelt of non-permanent marshes coincides with an emergence of invertebrates that provide essential nutrients needed for early-breeding waterbirds (Batzer and Baldwin 2012). As the season continues and non-permanent marshes begin to dry, most waterbirds have hatched their brood and are using more permanent wetlands for foraging (Batzer and Baldwin 2012). However, as these wetlands draw down, the soil's seed bank is exposed and plant recruitment is stimulated. As an added benefit, the increased plant recruitment mobilizes nutrients that typically

would be static in inundated soil, resulting in an increase in primary productivity (Euliss et al. 2004, Johnson et al. 2005).

Waterbirds are highly valuable to humans. In terms of recreation, hunting is heavily reliant on the NP&PR, which produces as much as 80% of the continent's waterfowl game species (Batt et al. 1989). But, many people also value birds for purely observation with bird watching as a major pastime. In fact, bird watching is one of the most popular activities in the world, in 2001, bird watching in the United States generated \$85 billion in overall economic impact (Whelan et al. 2008). Hunting of waterfowl also stimulates the economy with each duck hunted in Canada being valued at \$26 CAN (Green and Elmberg 2014) and total economic value of waterfowl in North America approximated at \$118 million US/year (Kennedy and Mayer 2002).

In addition to providing economic and societal value through hunting and bird watching activity, waterbirds provide several important ecological services. For example, they are critical vectors for dispersal. Valk (1989), Amezaga et al. (2002) and Green and Elmberg (2014) note that waterbirds provide essential aquatic plant and animal species dispersal between isolated or ephemeral wetlands. They increase the diversity of adjacent catchments by passive transportation of aquatic organisms and plant propagules that lack the mobility to move between catchments independently. This movement influences biodiversity, locally and regionally. Moderate grazing by waterbirds can increase diversity of grasslands by regulating interspecific competition while also increasing productivity (Green and Elmberg 2014). Additionally, waterbirds decrease invertebrate prey populations and can have positive economic consequences when predation

occurs on pests such as non-biting midges and mosquitoes (Whelan et al. 2008, Green and Elmberg 2014).

Waterbirds use the NP&PR during breeding and brood rearing. During this period, many waterbirds rely on invertebrates as their primary source of protein, lipids and calcium to aid in egg and body development and to feed growing young (Batt et al. 1989, Wrubleski and Ross 2011, Silver and Vamosi 2012). The presence or absence of invertebrates has been shown to influence spring habitat selection by waterbirds (Wrubleski and Ross 2011). Due to their hydrologic isolation and cyclic dry period, non-permanent wetlands typically do not contain any fish. This unique quality is advantageous to invertebrates because fish presence reduces invertebrate richness, density and biomass (Helgen and Gernes 2001, Wrubleski and Ross 2011), with fishless wetlands supporting structurally distinct invertebrate communities (Cobbaert et al. 2010). Fish presence can also result in increased turbidity and reduced macrophyte cover (Wrubleski and Ross 2011, Green and Elmberg 2014). As fish prey on invertebrates, the lack of fish within non-permanent wetlands allows for increased invertebrate survivorship and stocks. This abundant secondary productivity is a significant contributing factor to the value of non-permanent wetlands to waterbirds (Helgen and Gernes 2001).

Breeding waterfowl are also attracted by the physical heterogeneity of the wetlands in the NP&PR. Relatively small, isolated wetlands provide defensible habitat where waterbirds will not be disturbed by other birds (Batt et al. 1989) and predators such as mink prefer more permanent wetlands (Ballard et al. 2014). Furthermore, waterbird diversity and abundance is generally higher as water depth decreases and hydrological diversity increases (Bolduc and Afton 2008). The shallow water in non-permanent marshes can result in an interspersed of mud flats and

water, which is ideal for waterbirds (Hands et al. 1991). Mud flats or shallow water allow ducks to dabble, a foraging behavior that is advantageous to small vulnerable waterfowl as they can feed while remaining aware of their surroundings, including predator activity (Johnson and Rohwer 2000).

Waterbirds rely directly on non-permanent wetlands for breeding and brood rearing and therefore require this habitat to complete their life cycle. Without this specialized habitat, waterbirds may be at risk of serious declines in populations. Thus, the presence or absence of waterbirds in a range of non-permanent wetlands may be an indication of overall wetland condition or disturbance. These aspects, coupled with their relative ease of sampling and relatability to the public, make waterbirds an ideal candidate as indicators of wetland condition.

#### **1.4. Disturbance & Policy**

Unfortunately for the wetlands and waterbirds, the retreating glaciers that shaped the landscape also left behind fertile soils with the potential for highly productive agriculture (Bartzen et al. 2010, Rashford et al. 2011). Additionally, the small size and inherent seasonal drying of typical non-permanent marshes means conservation is more challenging and less easily regulated compared to permanent shallow open water wetlands, putting non-permanent wetlands especially at risk (Clare et al. 2011). Despite their obvious importance, wetlands are increasingly being destroyed, drained or impaired. Over 75% of the NP&PR in Canada has been transformed in the past century, primarily through conversion for agriculture (Riley et al. 2007). Agriculture is the dominant land use for the two natural regions, Grassland and Parkland, which make up Alberta's portion of the NP&PR (Natural Regions Committee 2006). Conversion of pasture and

grassland to intensive crop production is predicted to continue as prices for agricultural commodities increase (Rashford et al. 2011). Additionally, climate change and associated increases in temperature will allow longer growing seasons that will allow more productive crops and a larger variety of crops, such as corn (Russell 1990, Schindler and Donahue 2006). Increases in cropping will mean more area converted to agricultural use and more irrigation. With this land transformation, already over 50% of wetlands have been lost through drainage and infilling (Beyersbergen et al. 2004). Not only are wetlands being lost through direct conversion to cultivated crops, but agricultural activities such as livestock operations, also cause wetland degradation through changes in hydroperiod, nutrient loading from fertilizer contaminated runoff and increased sedimentation (Rashford et al. 2011). Intensive livestock operations are expected to expand and require increases in feed for livestock that is grown on irrigated land, meaning even larger supplies of freshwater will be used (Schindler and Donahue 2006). Agricultural land use conversion coupled with predicted drying from climate change (Johnson et al. 2005, Schindler and Donahue 2006) puts these highly variable and productive marsh ecosystems at great risk. We know that agricultural activity can lead to increased loss of wetlands, but the extent to which the waterbird community in non-permanent marshes in Alberta is altered by agricultural activity in the wetland basin remains unknown.

The extensive wetland loss and degradation has led to the development of a new provincial wetland policy geared at conservation, mitigation and replacement, including restoration (Government of Alberta 2013). The Parkland and Grassland natural regions in Alberta are currently managed together under the Provincial Wetland Policy as the “white zone” (Government of Alberta 2013) and are characterized as one Ecozone (Prairies) by the Ecological

Stratification Working Group (1996). Despite the working classifications, these natural regions have significant structural and functional differences. The Grassland has minimal tree cover compared to the Parkland, which is a mosaic of trees, shrubs, and grasslands (Government of Alberta 2013). In order to evaluate compensation and restoration efforts and to effectively understand the value of existing natural wetlands, field-based assessment tools are needed that incorporate ground level data such as species composition and water quality information. Earlier studies have also stated the need for comprehensive ways to evaluate wetlands, which directly assess biological condition rather than using physical or abiotic measurements (Brown and Batzer 2001, Helgen and Gernes 2001, U.S EPA. 2002). Recent studies have addressed the need for quantitative wetland evaluation tools based on biological communities by developing multi-metric biological indicator (bioindicator) tools, such as Indices of Biotic Integrity (IBI), for use in permanent wetlands (Rooney and Bayley 2012, Wilson and Bayley 2012); however, little work has focused on the abundant, highly productive non-permanent (i.e. ephemeral, seasonal, temporary and semi-permanent marshes, sensu Stewart and Kantrud, 1970) wetlands of Alberta.

### **1.5. Bioassessment**

Biological variables or bioindicators can be used to indicate disturbance or monitor the integrity (capability of a system to support biological diversity, elements and processes that are expected in the ecosystems natural environment) through bioassessment or biomonitoring (Karr 1999). Disturbance can be defined as a cause such as a physical force, process or agent that results in a perturbation or stress (functional response) in an ecological system (Rykiel 1985). Bioindicators can be communities, species or even ecological processes that are used to assess the quality of the environment and how it is changing over time (Rader and Shiozawa 2001).

Bioindicators eliminate the need to measure every environmental variable to gauge the condition of a wetland and drastically decrease the amount of data and information collected, which is advantageous during the decision-making process (Cairns et al. 1993). Additionally, bioindicators respond to many environmental conditions and can indicate indirect, cumulative effects where physical or chemical variables cannot (Cairns et al. 1993, Karr 1999).

Bioindicators can integrate chemical, physical and biological conditions both spatially and through time (Karr 1999). Thus, an indicator that is characteristic of the environment and capable of quantifying the magnitude of stress can act as a surrogate for measuring every environmental or abiotic variable. Generally, when choosing indicators for assessment purposes, desirable characteristics of indicators include that they are: biologically relevant, socially relevant, sensitive, measurable, cost effective and that they lack redundancy (Cairns et al. 1993). An effective bioindicator will respond in a predictable way to disturbances (Cairns et al. 1993, Karr 1999). Bioindicators also need to be able to discriminate between reference and highly disturbed wetlands (human caused impacts) while remaining insensitive to natural temporal and spatial variation (Karr 1999). This means that chosen bioindicators need to be insensitive to the typical cyclic climate and any inter-annual variation that occurs naturally in NP&PR marshes. To evaluate the effectiveness of waterbirds as potential bioindicators, I will characterize the change in species composition between years to determine sensitivity to inter-annual climate variability. This thesis builds on the previous work by Rooney and Bayley (2012), Wilson and Bayley (2012); beginning to fill the knowledge gap for assessment tools for non-permanent marshes within the NP&PR of Alberta by characterizing waterbirds within these marshes and their response, not only to changing land use, but also to natural variation in hydroperiod due to variations in climate.

In summary, non-permanent wetlands are extremely valuable systems, yet they face great risk because of conversion to agricultural use. To effectively protect and restore these wetlands, we require an understanding of the species composition within them and how the assemblages may change as a result of land use changes or climatic variation. Waterbirds show high potential to act as sensitive biological indicators of wetland condition in non-permanent wetlands of the NP&PR and could also assist in the implementation of the new Alberta Wetland Policy.

#### **1.6. Thesis objectives and outline**

My goal in this project is to characterize the relationship between waterbird community composition and the extent of agricultural activity in the surrounding landscape. In addition, I will examine the sensitivity of this relationship to inter-annual climate variation and seek elements of the waterbird community indicative of land use that are relatively insensitive to climate variability. I will **1)** characterize waterbird composition in non-permanent marshes in the NP&PR; and **2)** evaluate the potential of waterbirds to serve as robust bioindicators of agricultural disturbance. I hypothesize that **1)** my response variables around waterbirds (e.g., diversity, guild structure, and community composition) will vary along a gradient in my predictor variables (e.g., % agricultural land use within a specified buffer); and **2)** waterbird community composition will vary between years if marked climatic variation occurs. To address these hypotheses, I will **1)** examine the waterbird community composition, diversity and guild structure in non-permanent marshes across a gradient in agricultural land use intensity; **2)** use this information to evaluate whether waterbird composition, diversity or guild structure can indicate the condition of non-permanent marshes in the NP&PR and; **3)** compare waterbird responses between two years that are representative of typical inter-annual variation in climate

conditions. The work to characterize waterbird communities will help evaluate the condition of non-permanent marshes across a wide range of agricultural activity, and could aid in evaluation of compensation efforts and restored wetland sites in the future.

Chapter 2 contains an examination of waterbird community composition and functional traits and their correlation with land-use variables. I find that waterbird diversity and community composition are sensitive to agricultural land use in both the Parkland and Grassland natural regions, although differences between regions are responsible for more variation in waterbird community composition than the extent of non-natural cover. I conclude that this regional difference is because of important differences in vegetation structure that arise from the absence of forest and shrubland in the Grassland region. Regardless, the sensitivity to agricultural activity suggests that waterbirds provide a useful indicator of agricultural disturbance, particularly if biomonitoring tools developed to detect effects of agriculture are tailored to either the Parkland or Grassland natural region.

Chapter 3 examines the inter-annual variation of waterbird communities. I find that waterbirds respond to the inter-annual variation in climate and the response or change in community composition between years is different between natural regions. I also find that changes within year are consistent across disturbance and wetland class. These data suggests that waterbirds are sensitive to natural climatic variability but with consideration of this sensitivity, I conclude that they retain potential as useful indicators in the NP&PR.

Chapter 4 provides a brief summary of findings, implications for monitoring and assessment, implications for the future of waterbirds with changing climate and land use, and finally recommended directions for future research.

## **2. Agricultural Fowl Play: Waterbird Sensitivity to Agricultural Disturbance**

### **2.1. Introduction**

The Northern Prairie and Parkland Region (NP&PR) is arguably the most important area in North America for shorebirds, waterfowl and wetland-dependent songbirds (herein, waterbirds) (Beyersbergen et al. 2004, Dahl and Watmough 2007). Wetlands typical of the NP&PR have uniquely cyclical hydrology that creates high biodiversity (Euliss et al. 2004). Furthermore, the density of wetlands can be up to 50 per km<sup>2</sup> (Beyersbergen et al. 2004). Due to the density of wetlands and their cyclic hydrology, the NP&PR is ideal habitat for migrating, breeding and brood rearing of waterbirds (Batt et al. 1989, Mitsch 2007).

Waterbirds provide many ecosystem services such as plant and aquatic species dispersal (Amezaga et al. 2002), local economic input through bird watching and hunting (Whelan et al. 2008) and general aesthetic value to the landscape (U.S EPA. 2002). Wetlands in the NP&PR are also recognized for their complex hydrological and biogeochemical functions, ecosystem services such as flood attenuation, drought mitigation, carbon storage and biodiversity (Mitsch 2007, Johnson et al. 2010, Goldhaber et al. 2014).

Despite these numerous services, as much as 50% of wetlands have been lost in the Canadian NP&PR due to increasing agricultural and urban development (Kennedy and Mayer 2002, Mitsch 2007). Agriculture is the main source of destruction of wetlands in the NP&PR (Schindler and Donahue 2006). Aside from drainage and infilling, wetlands that remain in the landscape that are adjacent to agricultural activities can also suffer physical and chemical alterations (Zedler and Kercher 2005, Rashford et al. 2011). Tillage of adjacent uplands

increases sedimentation into wetlands (Zedler and Kercher 2005), inputs of fertilizer can cause nutrient loading and lead to eutrophication (Schindler and Donahue 2006), and wetlands that are exposed to cattle undergo physical alteration due to compaction that reduces vegetative cover for nesting birds and increases turbidity (Bloom et al. 2013). Wetlands that are within a cultivated or pasture landscape also have much slower recovery rates when exposed to impacts than wetlands within a more natural grass or wooded landscape (Bartzen et al. 2010). Correspondingly, wetlands that are affected by agriculture will support different community compositions of waterbirds. Because of these numerous direct and indirect effects of agriculture on wetlands, it is likely that waterbirds using wetlands in agricultural landscapes will be influenced as well.

Wetland loss and degradation is compromising ecosystem functioning (Dahl and Watmough 2007) and habitat availability (Johnson et al. 2005), and is leading to declines in waterbird populations (Batt et al. 1989). Conservation initiatives such as the North American Waterfowl Management Program have been implemented to prevent further habitat loss and degradation in the NP&PR (Beyersbergen et al. 2004); however, impacts are still being documented across the region (Bartzen et al. 2010). As land use and anthropogenic disturbance continues to intensify, it is critical to determine and understand the extent to which ecological systems are experiencing loss of function and changing condition. Dahl and Watmough (2007) noted in a review of wetland status and trend monitoring that more comprehensive information is needed on the different types of wetlands and their functions. More comprehensive knowledge is also needed to ensure effective management and conservation of wetlands. This is particularly true for non-permanent marshes, which are so important ecologically but are relatively poorly studied, especially in the northern portion of the NP&PR.

Biomonitoring would help inform conservation and management of non-permanent marshes. This involves using biological variables, such as communities or species, to indicate the condition of an ecosystem (Cairns et al. 1993), while still integrating chemical, physical and biological conditions through time (Karr 1999, Rader and Shiozawa 2001). Biomonitoring can be used to condense diverse data into a single index that reflects disturbance, deliberately simplifying the ecological composition to more manageable amounts of information (Canterbury et al. 2000). Bioindicators have been shown to respond to many environmental conditions and can indicate cumulative, indirect effects (Cairns et al. 1993). Monitoring using an indicator species is not a new practice but the focus on single species as indicators has shifted and most bioindicator work now focuses on monitoring assemblages (i.e., groups of species or taxa) (Siddig et al. 2016) and less on measuring chemical and physical criteria (Guntenspergen et al. 2002). When using communities as bioindicators, the resulting tool yields a more robust assessment of ecosystem condition because it is a reflection of long-term cumulative effects of many stressors (Cairns et al. 1993). Additionally, re-calibration of a community-based biomonitoring tool will be less frequent in comparison to one that is measuring populations and responses to specific stressors or toxins (Cairns et al. 1993). The use of bioindicators and biomonitoring has been steadily increasing since the early 1990's and is predicted to continue due to applicability to many ecosystems and stressors and ease of communication to the broader public and decision makers when using bioindicators (Siddig et al. 2016). When selecting taxa to develop bioindicators, many factors are considered; prospects should be socially and biologically relevant, measurable, sensitive to stressors, interpretable and lacking in extreme sensitivity to natural cycles or succession (Cairns et al. 1993, Karr 1999, Rader and Shiozawa 2001).

Monitoring tools utilizing birds have been successfully developed (U.S EPA. 2002) because of their sensitivity to land use (Wilson 2012). Mensing et al. (1998) found that, out of six different taxa surveyed, birds were the best indicator of local landscape condition in small stream riparian wetlands. The other five taxa investigated were: vascular plants of wet meadow and shrub carr communities, amphibians, fish and aquatic macro-invertebrates. Bird diversity and richness were highly correlated with the extent of cultivated land within 500 m and 1000 m scale buffers and were also sensitive to the amount of wetland and forest cover (Mensing et al. 1998). In addition to their sensitivity to land use and disturbance, waterbirds represent excellent candidates for biomonitoring because of their ubiquitous nature and public appeal (U.S EPA. 2002). Despite their excellent candidacy as a bioindicator, relative to invertebrates and fish, little is known about the use of birds as indicators of ecosystem condition (Nevel et al. 2004).

I anticipate waterbird community composition, guild structure and diversity will be sensitive to the intensity or extent of agricultural activity in adjacent lands because land-use variables influence waterbird habitat selection (Kantrud and Stewart 1984, Mensing et al. 1998). My goal is to determine if landscape-level and site-level variables are predictive of waterbird community composition in the NP&PR of Alberta. To address this goal I will determine 1) if waterbird guild structure and community composition vary along a gradient in agricultural land use; 2) if there are distinct assemblages of waterbirds and what habitat traits at the local and landscape level are predictive of assemblage occurrence; 3) if certain waterbird assemblages are exclusive to either reference or highly disturbed conditions; 4) assess if these distinct assemblages are found across the entire study area or limited in distribution to either the Parkland or Grassland natural region; and 5) if these assemblages can be used to indicate the

level of agricultural disturbance affecting a wetland. I am interested in determining if waterbird community composition varies predictably with the extent of agricultural activity in the surrounding landscape to evaluate the potential for waterbird-based biological assessment of wetland condition.

## **2.2. Methods**

### *2.2.1. Study area and sampling design*

I conducted my study in the Parkland and Grassland natural regions of Alberta where agriculture, industry and urban developments are the dominant forms of human land use (Ecological Stratification Working Group 1996, Natural Regions Committee 2006, Bartzen et al. 2010). Undulating plains and glacial till are characteristic of the Parkland and Grassland natural regions (Beyersbergen et al. 2004). The Parkland is a mosaic of deciduous forest and grassland compared to the Grassland where tree growth is stunted by persistent dry conditions, creating a more homogenous landscape of grassland habitat. The Grassland is the driest and warmest natural region in Alberta; whereas the Parkland has an intermediate temperature and precipitation level (Natural Regions Committee 2006). The climate of both the Parkland and the Grassland functions on a moisture-deficit regime where evapotranspiration exceeds annual precipitation, more so in the Grassland than the Parkland (Natural Regions Committee 2006, Millett et al. 2009). Appendix 1 summarizes the mean temperature for the sampling periods and accumulated precipitation for each region. Within the Grassland, I focused on two of the natural subregions: the Dry Mixedgrass and Mixedgrass. Within the Parkland all sites were located within the Central Parkland natural subregion.

I sampled 48 non-permanent marshes within the NP&PR about monthly from May to September 2014. In each of the Grassland and Parkland natural regions, sites were evenly distributed among three sub-watersheds (Figure 2-1). Sub-watersheds were selected based on 1) being positioned wholly within either the Parkland or Grassland natural region; 2) being entirely contained within Alberta's borders; and 3) possessing a glaciolacustrine or glaciofluvial derived surficial geology. Within those sub-watersheds, I randomly selected wetlands such that they spanned a gradient in disturbance level and permanence class. In addition, site selection was conducted such that the sample of wetlands from each sub-watershed reflects the frequency distribution of wetland sizes within that sub-watershed, based on the Alberta Merged Wetland Inventory (Alberta Environment and Parks Government of Alberta 2014). Sites averaged 0.81 ha ( $\pm 0.12$  standard error,  $n=48$ ) in size and were spaced a minimum of 3.5 km apart to minimize spatial autocorrelation.

Selected wetlands also spanned non-confounding gradients in agricultural activity (i.e. disturbance) and hydroperiod (i.e. marsh permanence class). The provincial Merged Wetland Inventory (Alberta Environment and Parks Government of Alberta 2014) and Grassland Vegetation Inventory (Alberta Sustainable Resource Development 2009) was used to determine wetland size and class, whereas land cover was derived from the Agriculture and Agri-Food Canada Annual Crop Inventory Data (2015). Only Class II, III and IV (i.e., temporary, seasonal, and semi-permanent) marshes were considered because ephemeral wetlands are not managed under Alberta's provincial wetland policy (Government of Alberta 2013) or included in the provincial wetland inventory (Alberta Environment and Parks Government of Alberta 2014). Thus, I selected wetlands categorized on an a priori basis by percent natural land cover within a

500 m buffer around each wetland. A 500 m buffer was selected because Rooney et al. (2012) found that bird-based IBI scores from permanent open water (Stewart and Kantrud Class V) marshes were best predicted using this scale. For site selection and visualization purposes, wetlands were categorized as high (<25% natural cover), medium (25-75% natural cover), or low (>75% natural cover) disturbance; however, for analysis the exact percent cover of different land covers was used. Natural land covers included forest, open water, native grassland and wetland. Due to the level of agricultural activity in the Grassland natural region, where 73% of land is privately owned (Natural Regions Committee 2006, Bartzen et al. 2010), truly pristine reference sites are scarce if they exist at all. Consequently, I accepted wetlands in the “least disturbed condition” (Stoddard et al. 2006).

#### 2.2.2. *Bird surveys*

Bird surveys were conducted by pairs of observers, following the methods of Wilson and Bayley (2012). In brief, surveys comprised a visual survey and an acoustic point-count survey and were conducted on two occasions at each site during the breeding season (May 19<sup>th</sup> –June 24<sup>th</sup>). Surveys were conducted twice to account for any differences in timing of breeding calls within the larger breeding season. The two counts were summed to ensure all birds using the wetland were included, regardless of whether their calls peak early or late in the breeding season. Generally, birds sing and call with the highest frequency between sunrise and 11:00 am (Alberta Biodiversity Monitoring Institute 2012), so all surveys were restricted to this time period. To account for variability in the time of day that species are actively calling, the order that sites were visited on the second visit was reversed (Wilson and Bayley 2012).

Upon site arrival, 10 min visual surveys were conducted from a pre-determined vantage point that had a minimally obstructed view of the open water, using a spotting scope and binoculars. Visual surveys were conducted before any other surveys to avoid flushing birds by entering the wetland. Surveyors then proceeded to the point-count location. In advance of fieldwork, aerial photos were used to select potential point-count locations and total site size dictated the number of point counts to be completed. Typically, only one point was necessary because the study wetlands were nearly all less than 1 ha in area. To minimize edge effects the point counts were situated in the center of the wetland (Alberta Biodiversity Monitoring Institute 2012). Sites larger than 1 ha necessitated multiple points counts. In this case, point counts were situated at least 200 m apart and 100 m from any upland, following the protocol devised by U.S EPA. (2002). If multiple point counts were necessary at the same site, the results were summed. Each point count comprised one 8-min survey where all auditory or visual detections of waterbirds were noted and identifications were made following the American Ornithologists Union Standard. Information used to determine functional groups of bird species such as feeding traits, preferred habitat and migration patterns was retrieved from the Birds of North America Online (Rodewald 2015). Where feasible, waterbird surveys were conducted during ideal conditions and surveys were deferred on days when wind or rain prevented auditory detection of birds or reduced bird song because inclement weather was recognized as a potentially limiting factor (U.S EPA. 2002, Alberta Biodiversity Monitoring Institute 2012). The Beaufort Wind Scale (Appendix 3) was used to determine wind speed prior to each survey following recommendations of Downes (2003), Alberta Biodiversity Monitoring Institute (2012). If wind exceeded a force of 3 (loose paper lifted, small tree branches moving) surveys were suspended until wind died down.

### 2.2.3. *Site level characterization*

Site level data were collected on the area of the wetland comprising open water, woody vegetation, and robust emergent vegetation forms by walking the perimeter of these vegetation types with a sub-meter latitude/longitude accuracy GPS (Juno Trimble T41; SXBlue II GPS Receiver) to delineate them. Plant assemblages were delineated based on the dominant (>25% of a patch) species and growth form (robust emergent, narrow-leaved emergent, shrubs, standing dead, etc.). The sum of all patches with the same dominant species and growth form comprised a vegetation assemblage's total area. Polygons were produced for each vegetation form and then GIS was used to calculate the area of each polygon for each wetland. In addition, I monitored abiotic variables known to influence waterbird habitat selection. This included staff gauges at each wetland to measure maximum and minimum water levels based on about monthly visits between May and September.

### 2.2.4. *Statistical analysis*

Clarke (1993) proposed a framework for non-parametric analysis of community data to assess anthropogenic impacts on biological systems that includes 1) displaying community patterns graphically 2) identifying taxa responsible for wetland clustering and 3) linking community patterns to environmental/land use variables. This framework was used with slight modifications to evaluate the response of waterbirds to varying levels of agriculture. Following the recommendation of McCune (2011), bird abundance data were log (x+1)-transformed before performing analysis to normalize their distribution and reduce the influence of numerically dominant species. In addition, rare species occurrences ( $n < 2$ ) were removed to reduce noise.

To determine if waterbird communities are sensitive to differing land-use variables, specifically the extent of agricultural activity within a 500-m buffer surrounding the wetland, I conducted nonmetric multidimensional scaling (NMS) ordination. Ordination was performed on the Bray-Curtis distances (Clarke and Warwick 1994) among wetlands spanning a gradient in agricultural land cover extent based on waterbird species abundance data, using PC-ORD version 6 (Peck 2010, McCune 2011). This ordination also allowed me to visualize which sites possessed similar waterbird community composition and which sites differed. I then used vector overlays reflecting the correlation between NMS axes and the abundance of waterbird species to identify species closely aligned with those differences in community composition. I ran the NMS ordination 50 times with randomized data and 50 times with real data to determine the optimal number of dimensions, and then re-ran using the starting coordinates that provided the lowest stress value for the final solution. Finally, I applied a Varimax rotation, which is a rigid rotation of the ordination solution that aligns the dimension explaining the largest proportion of variance in the community composition data with the first ordination axis (McCune 2002).

Second, I explored how variation in community composition among wetlands related to different waterbird functional guilds. I classified waterbird species by their feeding and nesting habits and then overlaid vectors reflecting this trait data on the NMS ordination of differences in species abundance. Third, I explored how variation in community composition among wetlands reflected differences in surrounding land cover by applying a vector overlay where vectors reflected the correlation between percent composition of the landscape within a 500 m buffer around each wetland and the NMS ordination axes based on differences in species abundance among wetlands. Most of the variation in waterbird community composition was aligned with natural region that the wetland was located in; therefore, I conducted further ordinations with the

regions separated in case large differences in community composition between natural regions were masking other patterns in community composition important within region.

To test whether variation in community composition among wetlands reflects distinct assemblages of waterbird species, I used a combination of cluster and indicator species analysis (ISA). I used cluster analysis to assign samples to discrete groups based on the similarity of the redundant pattern of the waterbird abundances. My cluster analysis followed the hierarchical agglomerative polythetic process and the flexible beta linkage method (-0.250) was used in combination with Bray-Curtis distance measure, following recommendations of Peck (2010). ISA was used as an objective criterion for pruning the resulting dendrogram (McCune 2002). ISA assigns a species to each cluster that is indicative of the group based on fidelity and specificity, i.e. the abundance of a certain species and its constancy to a specific group (Dufrene and Legendre 1997). Unlike previously developed methods, ISA compares abundances only within species not among different species (Dufrene and Legendre 1997). After an indicator value is assigned to each species by calculating the relative frequency and abundance in each group, a Monte Carlo test of significance was performed with 4999 randomizations. The most informative level in the dendrogram can be determined by the cluster step that yields the smallest average p-value from an ISA analysis (McCune 2002). Thus, by averaging the p-values of each species from the Monte Carlo randomizations and determining the amount of clusters that returned the lowest average p-value, I was able to find the ideal number of clusters that retained maximum information about group composition while having high value indicator species. I also tested whether diversity differs significantly among the resulting waterbird assemblages. I did this using nonparametric Kruskal-Wallis analysis on the calculated Shannon

Diversity Index with SYSTAT version 13.0 (SYSTAT 2007). I then used a nonparametric multiple pairwise comparison test to determine how waterbird assemblages differed significantly from one another in terms of Shannon Diversity.

Lastly, I developed a model using site-level environmental variables and land use variables to predict which assemblage would occur at a given wetland, using classification and regression tree analysis (CART). CART functions by finding the predictor variable that is able to split the wetlands into groups in a way that maximizes homogeneity in terms of the wetland group's observed waterbird assemblage (Breiman 1984). Waterbird assemblage was derived from clustering, as described above. I used R (R Core Team 2013) with the tree package (Ripley 2014) to build and validate my classification tree. The splitting method used was the default, 'deviance' method (Ripley 2014). The resulting tree was pruned using k-fold cross validation, where  $k = 10$ . My model included predictor variables from both the landscape-level (% water and wetlands, % forest and shrubs, % crops, % exposed and urban development, and % pasture land cover within a 500 m buffer surrounding each wetland) and the site-level (% robust emergent vegetation, % open water, % woody vegetation and maximum water depth). Site-level data were converted from polygon area to percent composition of the total wetland area before inputting into my model.

## 2.3. Results

### 2.3.1. General results

Considering all 48 wetlands, I observed over 1700 individuals and 84 species during surveys. In the Parkland, I saw a total of 67 species compared to 51 species in the Grassland. Species

richness ranged from 6-20 species per site, with a mean richness per site of 13 species (+/ 0.46 standard error). Most commonly seen species were Red-winged Blackbirds (*Agelaius phoeniceus*), Blue-winged Teals (*Anas discors*) and Clay-coloured Sparrows (*Spizella pallida*) with occurrences of 221, 132 and 83, respectively.

### 2.3.2. NMS ordination

The final NMS ordination solution for both regions possessed 3 significant dimensions with a stress of 15.21 (acceptable) and an instability of <0.00001 (low) (McCune 2002) after 66 iterations (Figure 2-2). The cumulative variance represented by the recommended final solution was 70%. Following Varimax rotation, 34% of the variance of the distance matrix was explained by axis 1, 21% by axis 2 and 15% by axis 3. As shown in Figure 2-2, axis 1 segregates the Grassland and Parkland wetlands. The abundance of Black-capped Chickadee (*Poecile atricapillus*), Clay-coloured Sparrow, American Robin (*Turdus migratorius*) and Yellow Warbler (*Setophaga petechia*) are negatively correlated with axis 1 scores, whereas abundances of Marbled Godwit (*Limosa fedoa*), Willet (*Tringa semipalmata*), Gadwall (*Anas strepera*) and Northern Shoveler (*Anas clypeata*) are positively correlated with axis 1 scores. Similarly, trait-based vectors reveal that waterbirds dependent on trees for feeding and nesting correlated negatively with axis 1 and waterbirds that nest on the grass/ground and feed on the ground or in water are positively correlated with axis 1. Lastly, axis 1 segregates land-cover differences with a negative correlation of % Forest and Shrubs and positive correlation with % Grassland. Fewer species are correlated with axis 2. Red-winged Blackbird abundances are negatively correlated with Axis 2, whereas Western Meadowlark abundances are positively correlated axis 2. Axis 2 only slightly segregates functional traits compared to axis 1; waterbirds that are dependent on

marsh habitat for foraging and nesting are negatively correlated with axis 2. Axis 2 segregates low and high disturbance landscapes, with disturbed land-cover types being negatively correlated with axis 2 scores and % Grassland being positively correlated with axis 2 scores. Axis 3 is presented in Figure 2-2 (e) but does not segregate disturbance or region and is not correlated with any bird species or land-cover and trait variables; thus, it is not described further.

Because the NMS of the combined regions showed strong clustering by region, I conducted separate NMS ordinations on Grassland and Parkland sites to determine correlations with the agricultural gradient within each region. The final NMS solution for the 24 Parkland sites recommended 3 dimensions with a stress of 12.28, an instability of <0.00001 after 65 iterations (Figure 2-3). The cumulative variance represented by the final solution was 67%, with 50% represented by axis 1, 21% by axis 2 and 15% by axis 3. Overlaying vectors representing the correlation between NMS axes and species abundances, we see that the abundance of Red-wing Blackbirds, Redheads (*Aythya americana*) and Northern Shovelers are positively correlated with axis 1 and the abundance of Red-breasted Nuthatches (*Sitta canadensis*) are negatively correlated with axis 1. Axis 1 also segregates waterbirds functional traits similarly to the combined NMS with tree-dependent waterbirds negatively correlated with axis 1 and waterbirds dependent on the ground and aquatic habitats for nesting and foraging are positively correlated. Additionally, axis 1 separates disturbed sites from reference sites, with non-natural cover positively correlated with axis 1 and natural cover types negatively correlated with axis 1. Axis 2 of the ordination was positively correlated with Black-billed Magpies (*Pica hudsonia*) and House Wrens (*Troglodytes aedon*) and negatively correlated with Chipping Sparrows (*Spizella passerina*) and Swamp Sparrows (*Melospiza georgiana*). Figure 2-3(b) depicts that tree-

associated guilds are negatively correlated with axis 1 and marsh obligates and migrants are positively correlated with axis 1. Axis 3 is positively correlated with abundances of Gray Catbirds (*Dumatella carilinensis*), Alder Flycatchers (*Epidonax alnorum*) and Clay-coloured sparrows. Axis 3 score is also correlated with waterbirds that are dependent of fruit and shrub/scrub habitats. No correlations exist between axis 3 and the land-use variables, making it impossible to interpret in terms of human disturbance.

The final NMS solution for the 24 Grassland sites also recommended 3 dimensions with a stress of 13.43 and an instability of <0.00001 after 58 iterations (Figure 2-4). The cumulative variance represented by the final solution was 65%, with 33% represented by axis 1, 19% by axis 2 and 13% by axis 3. Overlaying vectors representing the correlation with waterbird species abundances (Figure 3-4b), it is evident that the abundance of Red-wing Blackbirds and Mallards (*Anas platyrhynchos*) are positively correlated with axis 1 and Savannah Sparrows are negatively correlated with the axis. As such, axis 1 also segregates functional traits as waterbirds dependent on trees for foraging are negatively correlated with this axis and omnivorous waterbirds and shrub-nesting species are positively correlated with axis 1. Axis 1 segregates low and highly disturbed sites and crop cover is positively correlated with axis 1. The abundance of Blue-wing Teals and Northern Shovelers are negatively correlated with axis 2 and Horned Larks are positively correlated with axis 2. Waterbirds dependent on the ground and aquatic habitats are negatively correlated with axis 2. Axis 2 also segregates land cover as tree and shrub cover are positively correlated with axis 2. Axis 3 is negatively correlated with abundances of Northern Pintail (*Anas acuta*) and Wilson's Phalaropes. No correlations exist between axis 3 and either land use variables or waterbird traits, so axis 3 is not described further.

### 2.3.3. *Cluster and indicator species analysis*

The results of my cluster analysis are depicted in Figure 2-2 (d), revealing six distinct groups of sites. Each group possesses at least one significant indicator species (Table 2-1), which can be used to differentiate the six groups and associated assemblages. The six assemblages also differed significantly in terms of waterbird Shannon Diversity Index (model I Kruskal Wallis:  $H=11.57$ ,  $p = 0.04$ ; Figure 2-6). I used a Dwass-Steel-Chritchlow-Flinger test for pairwise comparisons, which revealed that mean Shannon Diversity of waterbird assemblages indicated by “shallow open canopy”, “low disturbance” and “high disturbance emergent” are not significantly different ( $p \text{ value} \geq 0.05$ ). All other pairwise comparisons of waterbird assemblages revealed significant differences ( $p \text{ value} < 0.05$ ).

### 2.3.4. *CART*

The classification tree grouping wetlands based on their waterbird assemblage had an overall residual mean deviance of 0.95 and low misclassification error rate of 0.17, equivalent to an r-squared of 0.83. The final tree was pruned from 16 nodes to 10 using cross validation to reflect a tradeoff between misclassification costs and deviance (Figure 2-5). Variables that occur at the top of the mobile explain more variance in waterbird assemblage data than variables splitting terminal nodes. In general, land cover composition of the surrounding 500 m buffer was responsible for most splits, although the % robust emergent vegetation measured at the site level was an important differentiating variable. The predictor variable responsible for first split, i.e. providing the greatest deviance, was the percent cover of forest and shrubs. The 20 sites with more than 4.6% forest or shrub cover in the surrounding landscape are segregated from the 28

sites with less than 4.6% forest or shrub cover. Wetlands with less than 4.6% forest and shrub cover are then sub-divided based on the percent cover of robust emergent vegetation at the site, such that the 23 sites with greater than 11.34% robust emergent cover are most likely to support the “high disturbance emergent” assemblage, while sites with less than 11.34% cover of robust emergent vegetation are further sub-divided by the percentage of water and wetlands in the landscape. Sites with less than 0.54% water and wetlands in the surrounding landscape are further sub-divided based on pasture within the landscape: sites with less than 2.2% pasture will support “shallow open canopy” and with greater than 2.2% pasture support “deep open canopy”. Sites with greater than 0.54% open water in the surrounding landscape are further sub-divided based on maximum water depth: sites with a maximum water depth of less than 0.28 m, are likely to support “shallow open canopy” and sites with a maximum water depth greater than 0.28 m are most likely to support “deep open canopy”. The 28 sites that have more than 4.57% forest and shrubs in the landscape are also segregated secondly by the percentage of robust emergent vegetation at the site. Sites with greater than 0.56% robust vegetation are further segregated by the percent cover of water and wetlands in the landscape. Sites with greater than 10.23% water and wetlands in the landscape are most likely to support the “high disturbance emergent” assemblage and sites with less than 10.23% water and wetlands are most likely to support the “woody” assemblage. Sites with less than 0.56% robust vegetation are subdivided by the percent cover of pasture in the landscape and lastly, sites that have greater than 7.67% pasture are segregated by the percentage of exposed and urban cover in the landscape. Less than 7.67% pasture supports the “low disturbance” assemblage and exposed and urban landscape define the final separation of “low disturbance woody” and “woody” waterbird assemblages.

## 2.4. Discussion

The NP&PR is a critical landscape for waterbirds. Whether they are breeding, nesting, foraging or stopping over during migration, non-permanent marshes provide habitat that is tailored to the needs of waterbirds. However, compared to the larger Prairie Pothole Region the NP&PR is relatively understudied, particularly in Alberta where very little research has examined waterbird use of non-permanent marshes. The results of my study provide valuable insight into the nature of waterbird assemblages in the understudied NP&PR and investigate the importance of different site-level and landscape-level characteristics in determining what waterbird assemblages will occur at a particular wetland. My study results are especially important in anticipating what waterbird species could face losses or declines as a result of continued agricultural encroachment into wetland catchments.

I found that the differences between the Grassland and Parkland regions of the NP&PR are the primary determinant of waterbird community composition. Consequently, when Parkland and Grassland sites are analyzed in a single ordination, the big difference in waterbird community composition between regions partially masks the association between waterbird community composition and agricultural disturbance. When considering both regions jointly, the variation in community composition that is correlated with increasing agricultural disturbance on the second NMS axis, indicating that the variation in community composition associated with agriculture is orthogonal to variation in waterbirds that is associated with natural region. Interestingly, the variation in waterbird community composition between natural regions reflects differences in the amount of forest and shrubland between the Grassland and Parkland. However, when the two regions are evaluated separately, the importance of agricultural activity

within 500 m of the wetland boundary becomes the primary driver of variation in waterbird community composition in both the Grassland and the Parkland sites. Then, the second ordination axis in both the Grassland and Parkland ordinations is most strongly aligned with differences in forest and shrubland cover. Thus, tree and shrub cover within 500 m of the wetland boundary remains an important explanatory variable, even when the regions are treated separately. The regional ordinations also resulted in lower stress than the ordination with Grassland and Parkland included together. This indicates that when the regions were analyzed separately, the distances between sites in the ordinations are more closely representative of the Bray Curtis dissimilarity among sites in terms of their waterbird community composition.

Additionally, I found six distinct clusters of sample sites defined by similarities in waterbird assemblages, each with diagnostic taxa, and some reflected landscape level disturbances. When modeled, the sites were classified into groups reflecting attributes in the landscape and site level, but not necessarily the percent of non-natural land covers. This suggests that the waterbird assemblages may also be responding to factors other than just the amount of agriculture and the natural region, but waterbirds retain high potential as biological indicators. An important implication of these findings is that, any biomonitoring tool using waterbirds would be more sensitive to agricultural disturbances and have reduced noise if it were developed for each region separately.

#### *2.4.1. Variation in waterbird community reflects regional differences and agricultural gradient*

The Grassland and Parkland regions have structural differences in terms of vegetation and landform. For instance, the Grassland is typically lacking trees and shrubs and is generally very

flat whereas the Parkland has areas of undulating topography and abundant shrubs and trees (Natural Regions Committee 2006). Differences in bird traits are reflective of these differences in habitat: tree nesting species such as Black-capped Chickadee and American Robin were observed in Parkland sites, whereas grass nesting shore bird species such as Marbled Godwit and Willet were observed in the Grassland sites. Because of the higher occurrences of certain tree nesting species, such as the Black-capped Chickadee and American Robin, I also observed more year-round resident species in the Parkland compared to higher occurrences of short and long distance migrants in the Grassland. This is unsurprising as the Parkland is the northern most edge of NP&PR, so migrating waterbirds would tend to decrease at the ecotone (Keller et al. 2009). Additionally, the differences in habitat between the two regions would affect the ability of species to over winter (Newton 1998). Food availability is the major limiting factor in overwinter survival of bird species (Newton 1998). In the Grassland, the lack of trees and comparatively lower shrub density would mean that winter habitat would be sparse, in terms of cover and exposed berries/fruit with most of the vegetation covered in snow, making it unlikely for resident species to occupy the Grassland. Regardless, the difference in proportion of resident vs. migrant waterbird species has implications for wetland function in the two natural regions.

In general, waterbird species abundances that are associated with the agricultural gradient represent habitat generalists such as the Red-wing Blackbird, Black-billed Magpie and Mallard. All of these species have omnivorous tendencies; meaning regardless of the condition of the habitat they are occupying they will be able to forage effectively because they are not constrained or dependent on one food source. Removal of natural habitat typically causes a shift from complex vegetation structures and multiple available niches to homogenous habitats where

niche availability is reduced (Ehlers Smith et al. 2015). This allows generalist species to exploit commonly available resources, as they are more resilient to changes in habitat (Ehlers Smith et al. 2015).

The sensitivity to disturbance that I found is consistent with studies in comparable habitat completed by Bradford et al. (1998). Bradford et al. (1998) found that responses of birds in low and medium disturbance wetlands were variable, but in high disturbance habitats a threshold is reached that causes large shifts in bird community composition. In my study the waterbird species correlated with low-disturbance sites are less clear and consistent than the waterbird species associated with high-disturbance sites in my results. For example, Red-wing Blackbirds are consistently associated with disturbance regardless of region, whereas low disturbance sites are generally correlated with a larger number of waterbird species, and no species is consistent throughout ordinations. In addition to the changes in bird communities found in high disturbance wetlands, bird's use of the wetlands change based on the surrounding landscape.

Increases in breeding pairs of waterfowl are correlated with an increase in grassland landscapes, as opposed to landscapes that are dominated by cropland (Guntenspergen et al. (2002). In the Grassland, abundances of waterfowl such as Northern Pintails, Blue-wing Teals and Northern Shovelers were all correlated with gradients orthogonal to disturbances, consistent with Guntenspergen et al. (2002). These species are inversely correlated with non-natural cover; physical destruction of nests by cropping and cattle activity causes increased predation, which negatively affects nesting success of ground nesting waterbirds (Greenwood et al. 1995).

#### 2.4.2. Characterization of distinct waterbird assemblages

Despite regional differences, the waterbird taxa fell into obvious clusters in ordination space and six distinct assemblages were found (Figure 2-2 panel d). Although some clusters are tighter than others, results still indicate that waterbird assemblages are cohesive units with diagnostic species (Table 2-1). Thus, I conclude that the 48 wetlands sampled contained six distinct waterbird assemblages. Upon inspection of the groups, it is clear that agricultural disturbance is associated with particular assemblages, e.g., “shallow open canopy”, “low disturbance”, “high disturbance emergent” and “low disturbance woody” are associated with a gradient of non-natural cover types (Table 2-3).

“High disturbance emergent” is perhaps the most indicative of disturbance, as all sites indicated by the assemblage have at least 45% non-natural cover. The diagnostic species for this group are all opportunistic, habitat generalists. American Coot (*Fulica americana*), Red-wing Blackbirds and Redheads (*Aythya americana*), also all prefer wetlands with robust emergent vegetation, as they need strong vegetation to support nest structures (Yasukawa and Searcy 1995, Brisbin et al. 2002, Woodin and Michot 2002). Wetlands that are in areas of intensive agriculture or have been modified from their natural state have been shown to experience greater water-level fluctuations due to altered drainage and infiltration capacity of non-natural cover (Euliss and Mushet 1996, van der Kamp et al. 1999). Subsequently, these wetlands develop plant assemblages that are robust and tolerant of deeper water levels and increased water-level fluctuations such as cattails (Euliss et al. 2004). Besides the species that are indicative of this assemblage, waterbirds also within the assemblage with generalist behavior include: Black-billed Magpie, Killdeer and Black Tern. The indicator species for the “high disturbance

emergent” group all represent excellent candidates for bioindicators of disturbance in the Parkland.

Similarly, “shallow open canopy”, “low disturbance” and “low disturbance woody” generally represent low disturbance sites. “Shallow open canopy” differs from the latter two groups because it is characterized by grassland in the landscape and a lack of forest and woody vegetation. “Shallow open canopy” also lacks robust emergent vegetation at the site level (Table 2-2). The diagnostic species for this group is appropriately Le Conte’s sparrow. Le Conte’s Sparrow is a grassland species that prefers open habitats with abundant fine vegetative cover, particularly sedge meadows at the edge of marshes. However, Le Conte’s sparrow is the only indicator species and is only marginally significant for “shallow open canopy”, signifying that this assemblage may be more representative of a catch-all rather than a cohesive group of co-occurring species. “Low disturbance”, and “low disturbance woody” assemblages have forest and shrubs in the landscape, but at the site level. Only “low disturbance woody” has any woody vegetation present. Consequently, diagnostic taxa for the “low disturbance woody” assemblage reflect the site-level characteristics and are tree/shrub dwelling and nesting species. However, none of the indicator species are particularly representative of low disturbance habitat. In fact, Chipping Sparrow (*Spizella passerina*), Black-capped Chickadee and White-throated Sparrow have affinities for human modified habitats and fragmented patches of land (Rodewald 2015). Thus, their identification as indicators may be more reflective of site-level characteristics than landscape-level stressors.

In contrast, the diagnostic taxa for the “low disturbance” assemblage represent more sensitive species. Baird’s Sparrow in particular is well known to be area sensitive (Green et al.

2002). Baird's Sparrow was once one of the most common grassland bird but due to increasing agriculture, is now uncommon to rare and only locally abundant in large tracts of native prairie (Green et al. 2002). The other species that make up the "low disturbance" assemblages are also more sensitive species such as Northern Pintail and Sprague's Pipit (*Anthus spragueii*). Northern Pintail is one of the earliest waterfowl species to nest in the spring, immediately after ice-out (Greenwood et al. 1995). This means that they are dependent on non-permanent marshes in the spring because they will fill with water much before more permanent wetlands (Euliss et al. 2004). Being dependent on non-permanent marshes and sensitive to disturbance makes them an ideal indicator candidate. Sprague's Pipit is facing major declines due to their sensitivity to disturbances, especially cropping and high-intensity pasture (Davis et al. 2013).

Two groups were formed, "deep open canopy" and "woody", that don't show any particular correlation with disturbance or site-level characteristics; both groups span a gradient of high, medium and low sites and no obvious dominant land cover. The indicator species representative of each assemblage gives some insight as to what the groups could be responding to. "Deep open canopy" is indicated by a group of relatively common marsh obligate and grassland species, whereas indicator species for "woody" are both common tree/shrub dwelling birds. Perhaps with the inclusion of abiotic variables in the analysis each assemblage would be more closely associated with the agricultural gradient, but without any further variables I conclude that weak associations with agricultural land cover are occurring for "deep open canopy" and "woody".

Comparing the diversity among assemblages revealed only slightly significant differences and pairwise comparisons indicated three assemblages with no difference (Figure 2-6). My

results are consistent with literature that often finds diversity indices inconsistent and statistically unreliable (Karr 1999). Although, human activity is typically credited for reducing diversity it is not always the case, and in my results the assemblages associated with low disturbances were not the ones with the highest diversity.

#### *2.4.3. Landscape and site-level characteristics predict waterbird assemblages*

Results of CART confirmed what I found in ordinations, cluster and ISA analyses; strong correlations with natural cover types and site-level characteristics and a secondary correlation with agricultural cover types. Forest, shrub, robust emergent vegetation and water within a 500 m buffer of sites accounted for the greatest proportion of variance in the model. In contrast, the only non-natural land cover variables selected by the model were urban and exposed land and pasture. These results indicate that a combination of land use variables at the 500 m buffer and site-level characteristics are influencing the distinct assemblages of waterbirds that occur. CART results were not entirely reflective of cluster results and 17% of sites were misclassified indicating that predictor variables in the model were not exhaustive (Table 2-4). These misclassifications confirm that ‘catchall’ waterbird assemblages are present. The “woody” assemblage has the highest occurrence of misclassification and in the classification tree it is present in some proportion in five terminal nodes. This may also explain the poor association with landscape and site-level variables and the “woody” assemblage observed in the ordinations. In contrast, the “high disturbance emergent” assemblage is only present in two terminal nodes, further confirming the potential of the “high disturbance emergent” assemblage as a bioindicator of agricultural impact. The results also suggest that forest cover is confounded with region because there is limited woody vegetation present in the Grassland, but also forest cover is

inversely correlated with cropland cover in the Parkland. Brazner et al. (2007) found similar results when evaluating the confounding effects of geographic features on indicators within Great Lakes wetlands. Their results indicated that macro-scale factors such as ecosection, lake wetland type and wetland area have a greater influence on indicator response (including birds) than land use (Brazner et al. 2007). Brazner et al. (2007) suggests mitigating challenges by developing indicators using the residual variance remaining after removal of variance associated with geographical region or by simply developing indicators within geographical subsets.

#### *2.4.4. Implications*

We know that birds can be indicators of overall habitat conditions, particularly vegetation structure, type and form. Other authors have found waterbirds to be indicative of disturbances at the landscape scale (Bradford et al. 1998, Canterbury et al. 2000, Naugle et al. 2001). My results support this conclusion because next to the variance in community composition associated with natural region, natural vs. non-natural land cover was most strongly associated with variance in waterbird community composition. Specifically, the extent of cropland, urban and exposed land cover within 500 m around each wetland were predictive of which waterbird assemblage would occur in a wetland. Waterbirds may also be sensitive to site-level characteristics, such as invertebrate structure and abundance (Cooper and Anderson 1996), and abiotic variables such as organic matter (Nevel et al. 2004). Likely, variables such as these, which I did not include in my model or ordinations, would improve my predictions about waterbird community composition. I believe that with the inclusion of abiotic and biotic variables that can influence habitat selection the correlation with disturbance will be even greater. In conclusion, waterbirds appear to have

excellent potential to serve as indicators of agricultural disturbance in non-permanent marshes of the NP&PR.

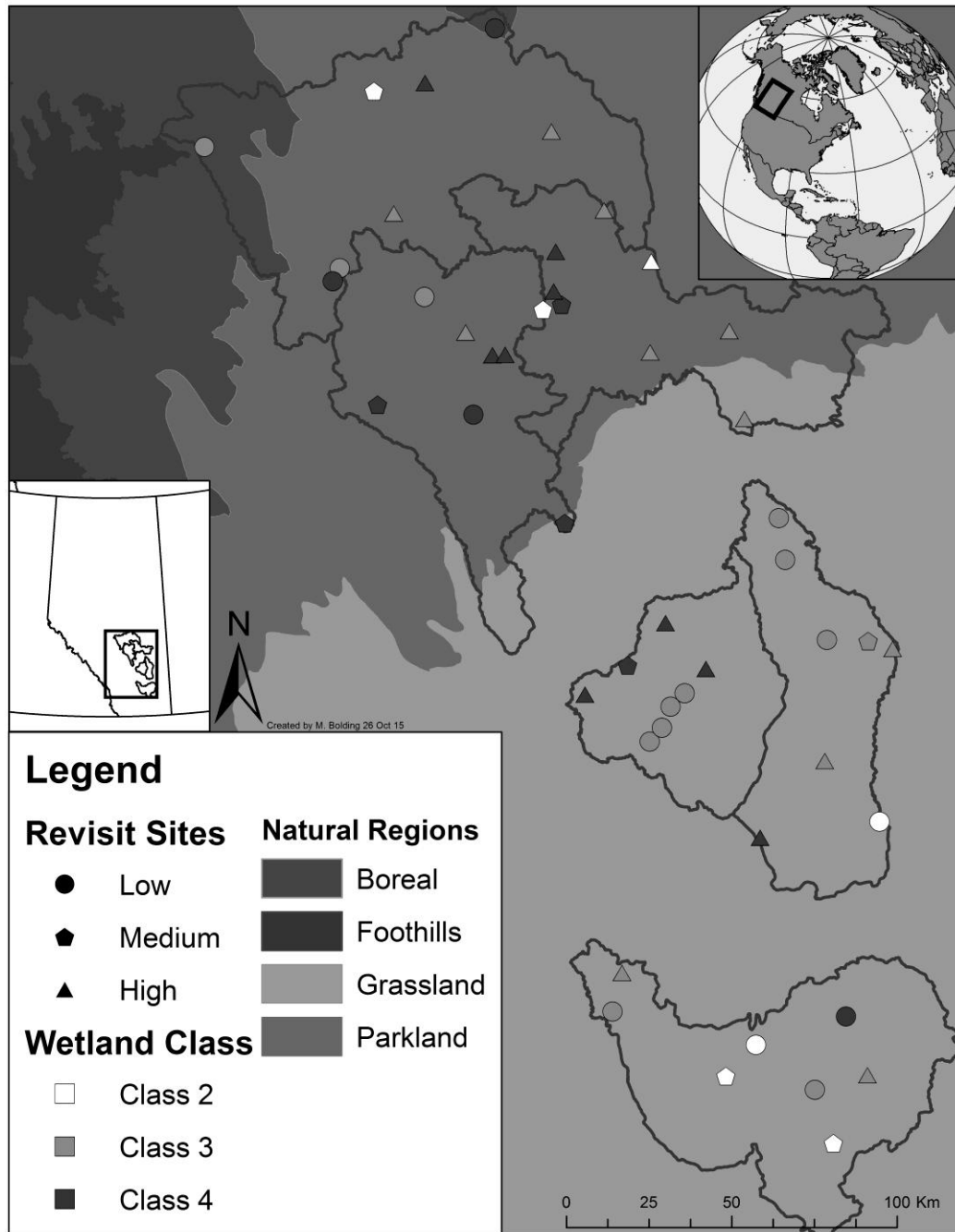
I found one waterbird assemblage was particularly associated with disturbed landscapes: the “high disturbance emergent” assemblage. In contrast, low disturbance landscapes might support the “shallow open canopy” assemblage or the “low disturbance” assemblage. Although these assemblages did not differ in terms of their alpha diversity (sensu Whitaker (1972); Figure 2-6), this has important consequences in terms of beta and gamma diversity. As agricultural land use conversion continues and agricultural activities intensify, we anticipate that more and more wetlands will move to support only the “high disturbance emergent” assemblage, and thus the other five assemblages identified in my thesis will become rarer. Consequently, measures of alpha diversity may fail to detect agricultural encroachment, and eventually gamma diversity as well, and are both perhaps a poor candidate for use in biomonitoring. Further, because the traits in terms of nesting and feeding habit differ among assemblages, this will also have an impact on wetland function.

Ecological impacts of a shifting community are broad. We will see a reduction in probing and foliage gleaners and an increase in omnivore feeding types and a reduction in ground nesting and an increase in floating nesting habits. These results indicate that wetlands are shifting from diverse habitats with many different available niches to habitats with limited variability and niches that are filled by generalist species that are less sensitive to surrounding agriculture. If wetlands continued to transition to habitats that do not fill the needs of specialists that have specific habitat requirements, more sensitive species may decline before they are able to adapt to disturbed wetland condition. Waterbirds that forage on vegetation and invertebrates in and

around the wetland contribute to the structure of communities and overall nutrient cycling (Green and Elmberg 2014). Intermediate disturbance to vegetation and invertebrates because of foraging creates higher diversity than wetlands that have no waterbirds and keep dominant species in check. The increased diversity will have an effect on the primary productivity of the wetland. For instance, if shore birds are lost from a wetland and only dabblers remain, the shallowest water where dabblers do not forage may become overgrown with macrophytes. Waterbirds are also prey for many species in the landscape surrounding the wetland, such as mink, fox, badger and snakes. If waterbird use of wetlands decreases, these mammals will also suffer because of increasingly limited food availability.

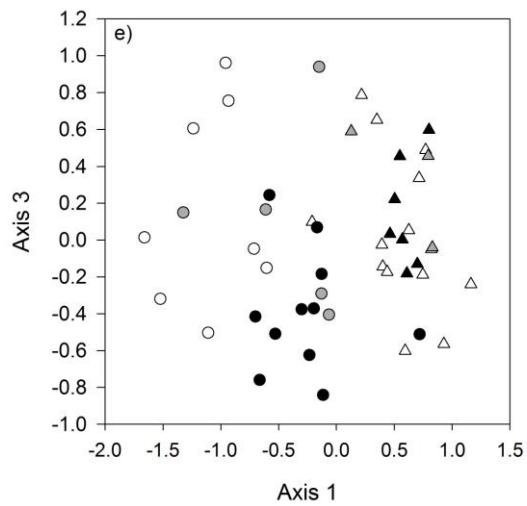
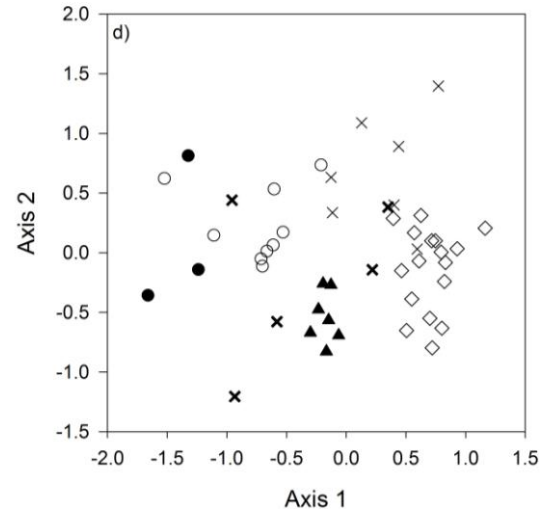
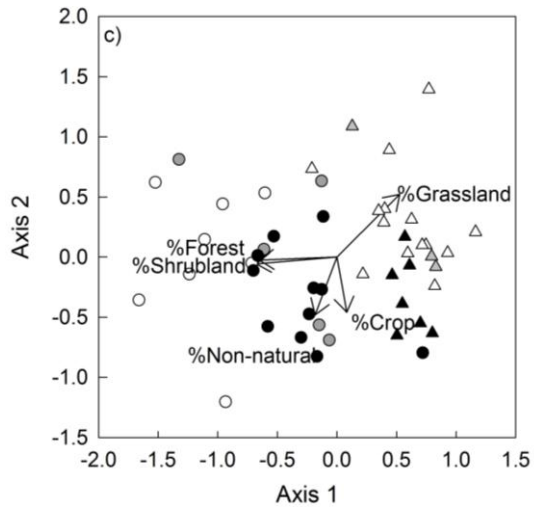
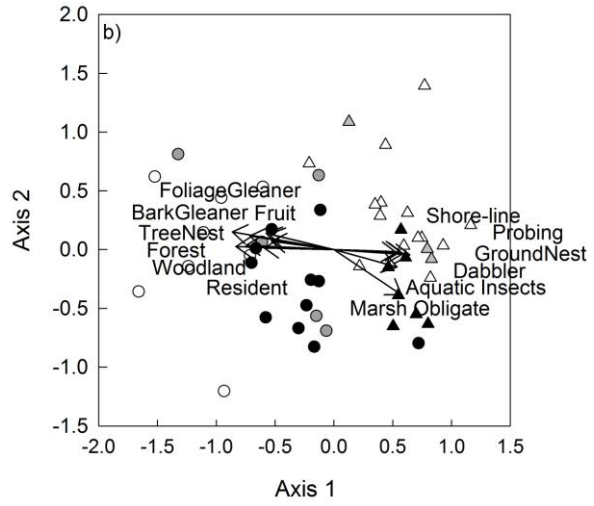
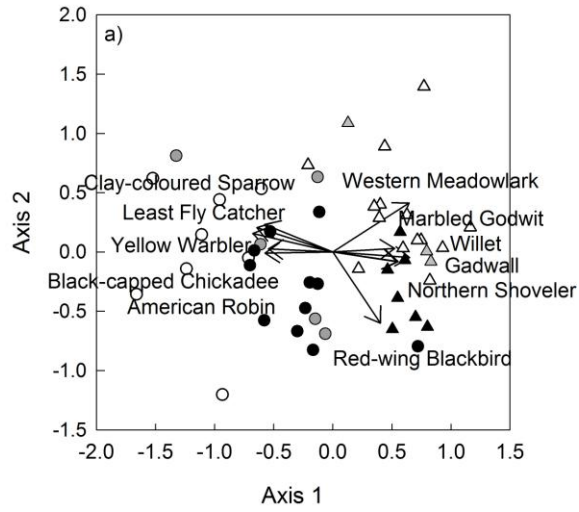
This shift may reduce the value of wetlands as wildlife habitat, which is an important wetland function and subsequently effects wetlands cultural, social and economic value. Wetlands are valued because they are aesthetically pleasing and contain interesting waterbird species that are typically not seen in an urban setting. If the birds in wetlands shift to more common species that are not of value for bird watchers and hunters, the value of the wetland decreases and the motivation to protect them decreases. If agricultural degradation is extensive enough, impacts will not be limited to the site level but eventually affect the regional diversity of species and an area that is critically important for breeding waterbirds may become unused.

2.5. Figures and Tables



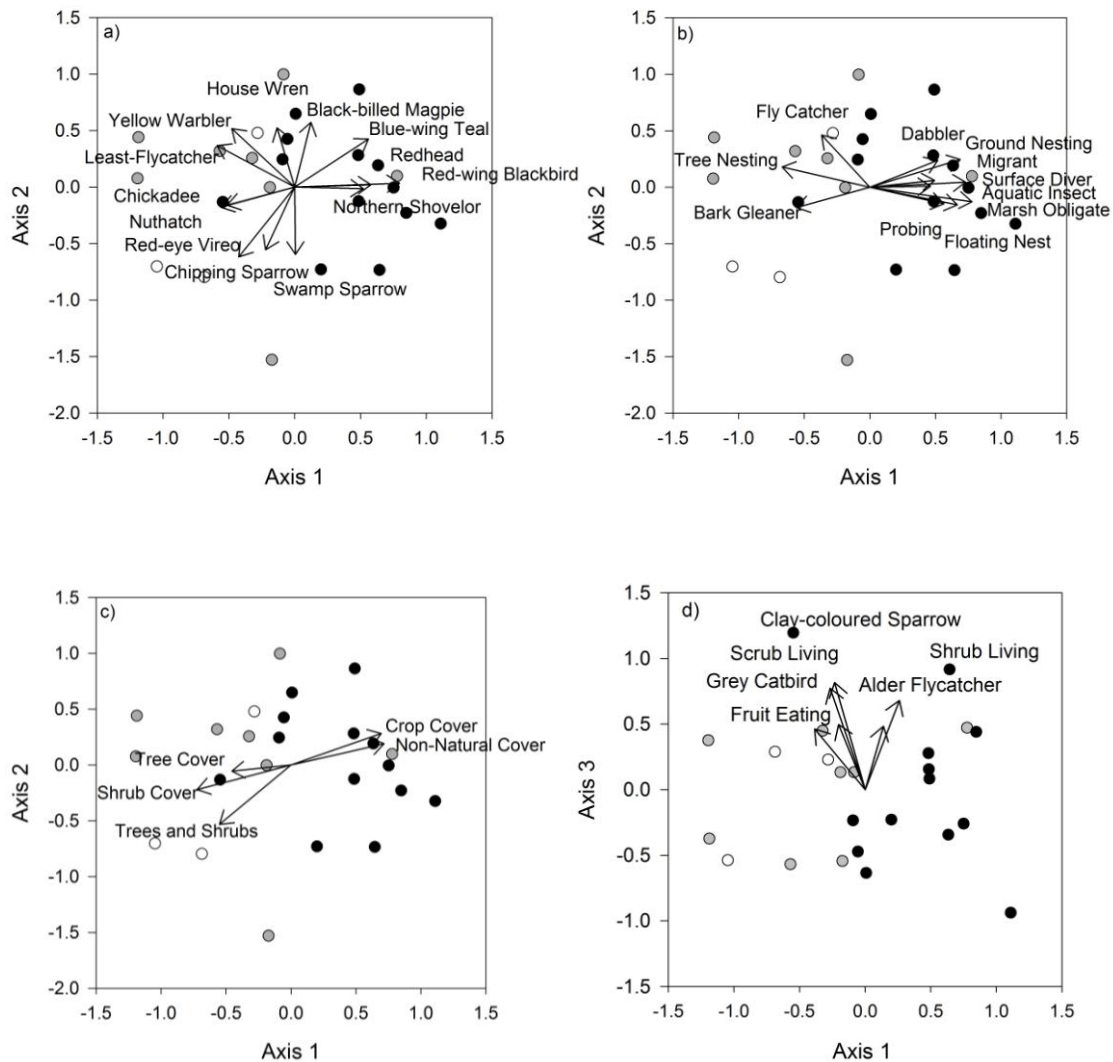
**Figure 2-1: Map of 48 study wetlands.** The sample sites are coded by shape based on disturbance class (land cover type within a 500 m buffer); circles are <25% non-natural cover,

pentagons are 25-75% non-natural cover and triangles are >75% non-natural cover. Sites are color coded by wetland class; white represents class 2 wetlands, grey represents class 3 and black sites are class 4 wetlands. Sub-watersheds are overlain within their respective natural regions.



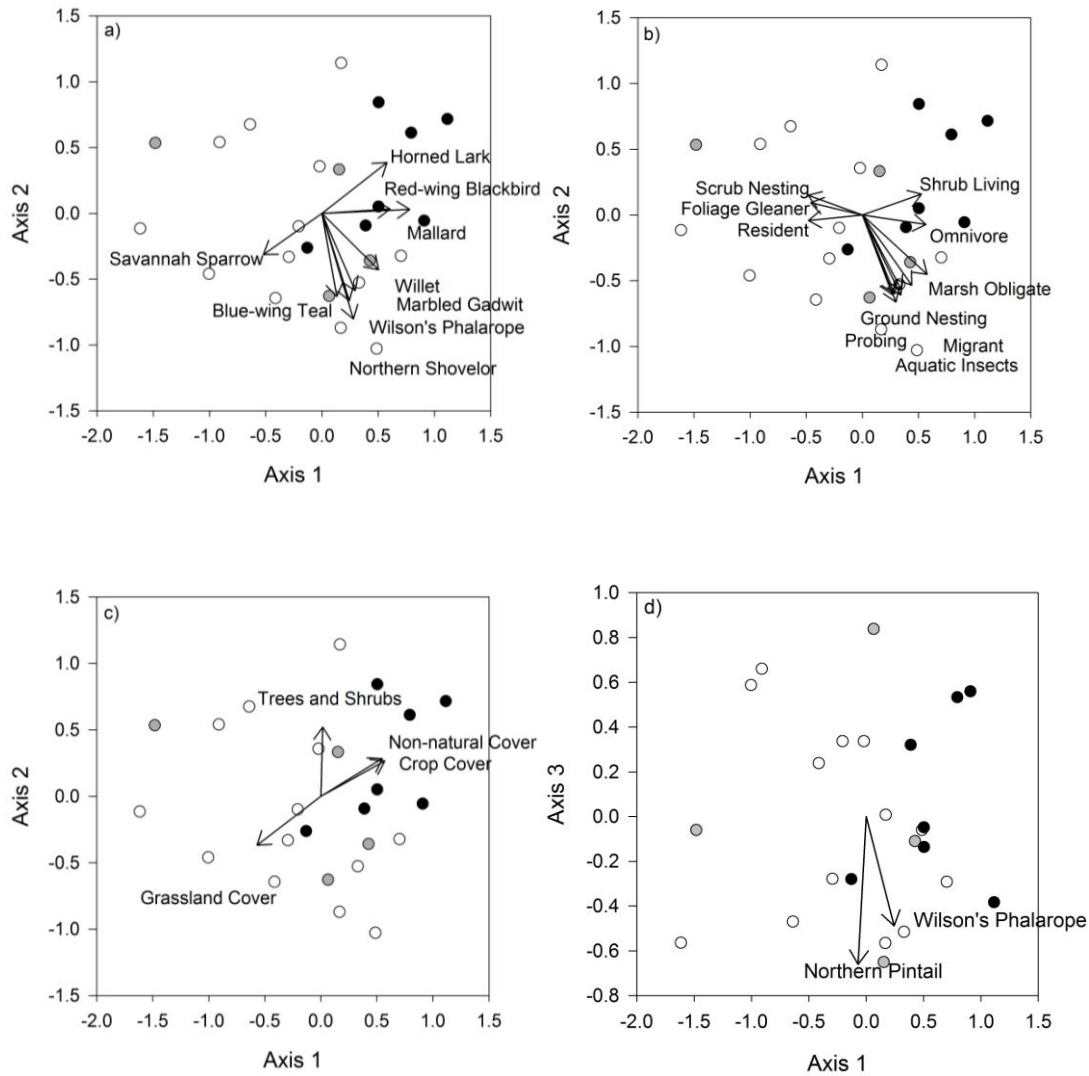
**Figure 2-2: Ordination of all wetlands.**

(a, b, c, e) Circles represent Parkland sites; triangles are Grassland sites. (a, b, c, e) Sites are coded by disturbance; white <24% non-natural cover, grey 25-75% non-natural cover and black >75% non-natural cover. (d) Sites are coded by waterbird assemblage, as determined by cluster analysis. Crosses depict “shallow open canopy”; diamonds represent “deep open canopy”; bold crosses depict “low disturbance”; white circles are “woody”; black circles represent “low disturbance woody”; and triangles depict “high disturbance emergent”. (a) Vectors represent the correlation between waterbird taxon and ordination axes. (b) Vectors represent the correlation between waterbird functional traits, habitats, foraging habit, nesting habit and ordination axes. (c) Vectors represent the correlation between percent of different land cover types and ordination axis. All vectors have Pearson’s correlation coefficients >0.25 with at least one NMS axis.

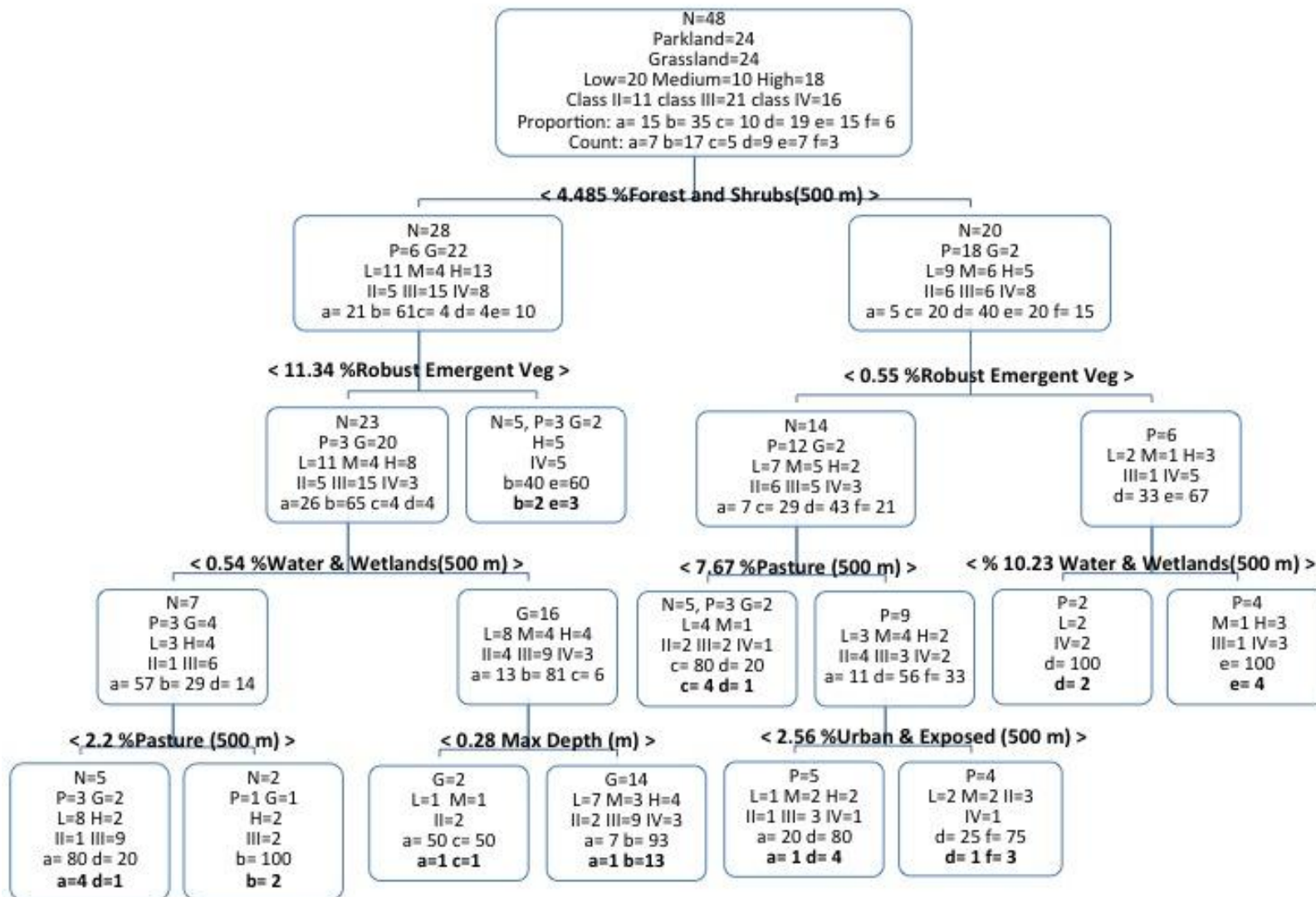


**Figure 2-3: Ordination of Parkland sites.**

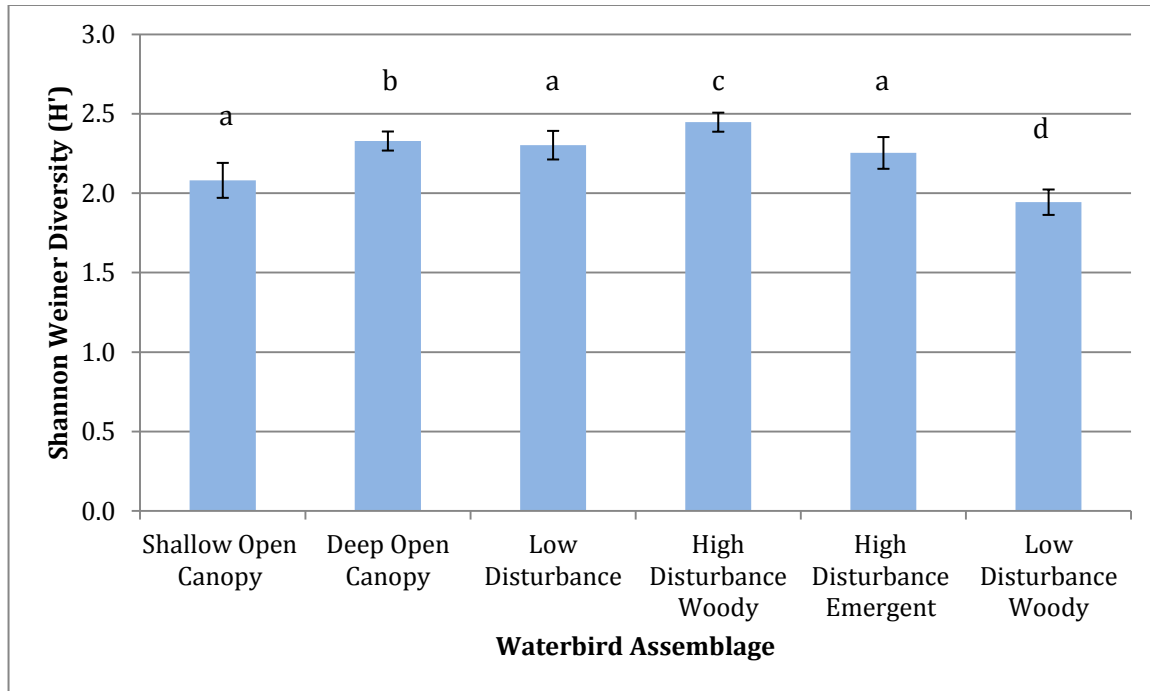
Symbols reflect disturbance level; white <24% non-natural cover, grey 25-75% non-natural cover and black >75% non-natural cover. (a & d) Vectors represent the correlation between waterbird taxa and ordination axes. (b & d) Vectors represent the correlation between waterbird functional traits, habitats, foraging habit, nesting habit and ordination axes. (c) Vectors represent the correlation between land cover metrics and ordination axis. All vectors have Pearson's correlation coefficients >0.25 with at least one NMS axis.



**Figure 2-4: Ordination of Grassland sites.** Sites are coded by disturbance; white <24% non-natural cover, grey 25-75% non-natural cover and black >75% non-natural cover. (a & d) Vectors represent the correlation between waterbird taxa and ordination axes. (b) Vectors represent the correlation between waterbird functional traits, habitats, foraging habit, nesting habit and ordination axes. (c) Vectors represent the correlation between land cover metrics and ordination axis. All vectors have Pearson's correlation coefficients >0.25 with at least one NMS axis



**Figure 2-5: Classification tree using landscape and site level variables.** If buffer is not noted, variable is site level characteristic. Thresholds that define the classifications are noted outside of the boxes. Proportion of each waterbird assemblage in each node is noted where “shallow open canopy” (a), “deep open canopy” (b), “low disturbance” (c), “woody” (d), “high disturbance emergent” (e), “low disturbance woody” (f). If the proportion of an assemblage in a terminal node is equal to 100, the node is pure. Parkland (P), Grassland (G), low disturbance (L), medium (M), high (H), class II (II), class III (III), class IV (IV). Where descriptors of variables in each node are equal to zero, they are removed and only remaining descriptors are noted. The actual number of sites that support each waterbird assemblage is noted in bold in terminal nodes.



**Figure 2-6: Waterbird assemblage and Shannon Diversity (H').** A shared letter indicates assemblages with non-significantly different Shannon Diversity values. Assemblages with significantly different mean Shannon Diversity values have different letters. Error bars represent standard error of Shannon Diversity.

**Table 2-1: Indicator species analysis results.** This table depicts indicator species deemed significant ( $p < 0.05$  based on a Monte Carlo test with 4999 permutations) predictors of each of the six waterbird assemblages identified by cluster analysis. The indicator value (IV) reflects the degree to which that species is both faithful and exclusive to the associated assemblage. An IV of 100 reveals that the indicator is only ever and always found in a given assemblage, i.e. perfect indication. The p-value is proportion (of 4999 iterations) of randomized trials in which calculated IV is equal to or greater than the observed IV.

Species	Waterbird assemblage	IV	p-value
Le Conte's Sparrow	Shallow open canopy	43.5	0.0400
Gadwall	Deep open canopy	51.5	0.0002
Willet	Deep open canopy	45.9	0.0116
Wilson's Phalarope	Deep open canopy	40.2	0.0380
Horned Lark	Deep open canopy	41.6	0.0444
Western Meadowlark	Low disturbance	39.7	0.0016
Northern Pintail	Low disturbance	59.9	0.0060
Baird's Sparrow	Low disturbance	33.3	0.0284
Least Flycatcher	Woody	66.0	0.0004
Yellow Warbler	Woody	61.1	0.0006
Red-wing Blackbird	High disturbance emergent	33.4	0.0002
Redhead	High disturbance emergent	78.4	0.0006
American Coot	High disturbance emergent	50.5	0.0186
Red-eyed Vireo	Low disturbance woody	66.7	0.0058
Red-breasted Nuthatch	Low disturbance woody	40.9	0.0132
Chipping Sparrow	Low disturbance woody	38.9	0.0134
Black-capped Chickadee	Low disturbance woody	34.2	0.0306
White-throated Sparrow	Low disturbance woody	38.2	0.0344

**Table 2-2: Waterbird Assemblages and associated site-level variables.** Maximum water depth, size and percentages represent averages of each assemblage.

Waterbird Assemblage	N	Size	Natural Region	Permanence Class	Max Water Depth (m)	% Woody Veg	% Robust Emergent Veg	% Open Water
Shallow open canopy	7	6696.85	Both	All	0.45	2.10	0.00	2.96
Deep open canopy	17	10978.75	Both	All	0.53	0.09	4.76	7.36
Low disturbance	5	4073.29	Both	All	0.38	0.00	0.00	12.49
Woody	9	7302.93	Both	All	0.45	30.67	6.23	7.67
High disturbance emergent	7	6677.50	Parkland	3&4	0.71	6.50	14.77	37.58
Low disturbance woody	3	7269.48	Parkland	2&4	0.48	27.68	0.00	3.23

**Table 2-3: Waterbird Assemblages and associated landscape-level (500m buffer) variables.** Percentages represent averages of each assemblage.

Waterbird Assemblage	% Urban Exposed	% Pasture	% Crop	% Forest	% Shrub	% Grassland	% Water
Shallow open canopy	2.47	11.46	18.20	0.03	2.19	62.24	3.41
Deep open canopy	3.82	11.24	38.64	0.01	0.51	39.71	6.07
Low disturbance	2.32	1.91	12.96	30.72	10.08	30.47	11.54
Woody	1.38	9.99	27.36	17.71	16.01	22.37	5.19
High disturbance, emergent	2.77	25.90	51.64	1.24	7.67	0.08	10.71
Low disturbance, woody	4.07	20.73	0.20	50.27	19.99	0.41	4.34

**Table 2-4: Misclassification table for the six waterbird assemblages.** Based on pruned CART model with 10 terminal nodes, rows are actual waterbird assemblages and columns are predicted waterbird assemblages. Row totals are indexed as number correct/number misclassified. Total misclassification rate based on k-fold cross validation 8/48 (16.7%), where k was 10.

	Shallow open canopy	Deep open canopy	Low disturbance	Woody	High disturbance emergent	Low disturbance woody	Totals
Shallow open canopy	5	0	1	1	0	0	5/2
Deep open canopy	1	15	0	0	0	0	15/1
Low disturbance	0	0	4	1	0	0	4/1
Woody	1	0	0	6	0	0	6/1
High disturbance emergent	0	2	0	0	7	0	7/2
Low disturbance woody	0	0	0	1	0	3	3/1

### **3. Inter-annual comparison of waterbird community composition**

#### **3.1. Introduction**

Globally, wetlands provide essential ecosystem services such as flood mitigation, increased local and regional biodiversity, carbon storage, drought resilience through groundwater recharge, and wildlife habitat (Batt et al. 1989, Mitsch 2007). Waterfowl, wetland-dependent songbirds and shorebirds, (herein, waterbirds) rely heavily on wetlands to complete their life cycle as they breed, nest, rear young and forage in wetlands (Batt et al. 1989, Valk 1989, Batzer and Baldwin 2012). Waterbirds also play essential roles in plant and aquatic species dispersal (Amezaga et al. 2002). Further, waterbirds provide great aesthetic value to a landscape and economic value through hunting (Whelan et al. 2008) and birding activities. Despite the multitude of beneficial services that wetlands and wetland-dependent birds provide, these unique habitats continue to be destroyed and degraded (Clare et al. 2011). In the Northern Parkland and Prairie Region (NP&PR), over 50% of wetlands have already been lost to agricultural conversion (Beyersbergen et al. 2004) and loss is predicted to increase as commodity prices continue to rise (Rashford et al. 2011). The loss of wetlands has resulted in a steady decline of waterfowl since 1955 (Batt et al. 1989, Mitsch 2007). Increasing losses of wetland habitat, and subsequently waterfowl, have made the need for effective wetland conservation and protection essential. To ensure that conservation and management of wetlands reflects the preservation of overall biotic condition or “health” of the wetland, monitoring tools are required.

Monitoring based on ecological health was described by Cairns et al. (1993) and Karr (1999) as a way of measuring the integrity of a water body based on the status of its living

components. By focusing monitoring on living systems that represent the cumulative integration of physical, biological and chemical conditions around them, monitoring is reflective of the overall condition (Karr 1999, U.S EPA. 2002, Burger 2006). Additionally, results from assessments that have biological endpoints are more interpretable and easier to communicate to managers and the public (Cairns et al. 1993, Karr 1999). Several taxonomic groups common in wetlands are capable of serving as indicators that are sensitive to environmental stressors; however, bioindicators must be able to discern human induced changes from the background noise of natural variation. Separating natural variation from human-induced variation is an on-going challenge when using bioindicators; generally the two cannot be separated entirely because human disturbance can exacerbate by natural variation or vice-versa (Karr 1999, Burger 2006).

Waterbirds are sensitive to wetland habitat quality (Wilson 2012) and they may respond predictably to surrounding land-use type and cover as I found in Chapter 2. Because of this sensitivity to wetland condition, waterbirds show strong potential to act as bioindicators. An ideal bioassessment tool using waterbirds as bioindicators would be applicable throughout the entire province and through both wet and dry periods; however, natural variation in temperatures, precipitation and differences in climate between natural regions could inhibit bioassessment tool development as these factors add background noise. Realistically, the ability to produce effective bioassessment tools could vary for each wetland class, type and natural region (Wilson 2012). Robust bioassessment tools have been developed using vegetation as a bioindicators in more permanent wetlands in the Parkland (Rooney and Bayley 2012, Wilson 2012) and Boreal (Raab 2010) natural regions, but bioindicators have yet to be developed for use

in the abundant non-permanent marshes throughout the NP&PR. Moreover, the potential utility of waterbirds as bioindicators in Alberta is relatively poorly studied.

Non-permanent wetlands (i.e. ephemeral, seasonal, temporary and semi-permanent marshes) (sensu Stewart and Kantrud 1970) have variable hydroperiods that depend on the water budget (van Der Kamp and Hayashi 2009), but typically they exhibit annual wet and dry periods (Stewart and Kantrud 1970, Euliss et al. 2004). This unique cycle is characteristic of the wetlands within the NP&PR and results in increased productivity and abundant plant and animal diversity (Sharitz and Batzer 1999, Niemuth et al. 2014). In addition to seasonal fluctuations, marshes in the NP&PR are also subject to large-scale climate oscillations as a result of interactions between three air masses: Maritime Polar, Maritime Tropical and Continental Polar (Natural Regions Committee 2006, Millett et al. 2009). The relationship between large-scale atmospheric circulations are still poorly understood due to their inherent instability (Jiang et al. 2014), but three dominant oscillations (2 to 3 year, 3 to 6 year and 6 to 12 year) have been identified that influence seasonal precipitation in Canada (Coulibaly 2006). Atmospheric circulations such as El Nino Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) also have significant influence on the surface temperature and precipitation in Alberta (Coulibaly 2006, Lapp and Kienzle 2013, Jiang et al. 2014). Sea surface temperature (SST) variability caused by the PDO drives winter precipitation in the Pacific Northwest and is particularly influential in Southern Alberta (Lapp and Kienzle 2013). Millett et al. (2009) conducted a study to reveal climate trends for the past century and found that as a result of these large-scale interactions, a strong precipitation gradient occurs across the NP&PR that causes the most north-westerly areas of the NP&PR to receive up to 600 mm/year less precipitation than

the extreme south-east of the NP&PR. The decreased precipitation is coupled with high evapotranspiration rates as a result of low humidity and high summer temperatures (Millett et al. 2009). However, this sharp precipitation gradient is moderated slightly by a north-south temperature gradient that causes relatively cooler temperatures and shorter growing seasons in the Northern NP&PR than the southern portions (Millett et al. 2009). Consequently, the hydrology within NP&PR is highly variable between seasons, years and decades. Adding to this natural variability, climate change is predicted to raise mean annual temperatures in the NP&PR 2-4 degrees Celsius by 2100 (Cambridge University and Stocker 2014) with slight increases in precipitation during the winter but very little increase during times when evapotranspiration is high (growing season) (Johnson et al. 2010).

The influence of inter-annual variability in climate on the reliability of plant-based bioassessment tools has been investigated by Euliss and Mushet (2011) and Wilson et al. (2013) with mixed results. Although no one has before examined the relative sensitivity of waterbird derived bioassessment tools to natural variation in climate, there is some reason to believe birds might be more sensitive than vegetation. Chin et al. (2014) found that waterbirds specifically are sensitive to changes in hydrology as a result of variable climate. The correlation between water depth and waterbird density is well understood in experimental systems, to the extent that practitioners are able to manage wetlands or water bodies to mimic natural fluctuations to increase use by waterbirds (Murkin et al. 1997, Ma et al. 2010). Waterbirds are intrinsically tied to water depth because it determines their ability to effectively forage, nest and rear young (Hands et al. 1991, Bolduc and Afton 2008, Baschuk et al. 2012). The foraging habit (e.g., dabbling, diving or probing) is defined by the morphology of a waterbird's bill and legs and

limits the depth of water that a species can utilize (Greenwood et al. 1995). Also, aquatic invertebrates can be influenced by changing water depth and are an important food source for waterbirds (Bolduc and Afton 2008). This effect on invertebrates will be particularly important in the spring and early summer when all waterfowl and shorebirds rely on invertebrates for protein to support egg development and brood rearing (Murkin et al. 1997). Thus, bird-based biomonitoring tools could be so sensitive to inter-annual variability in climate that it compromises the ability of tools to detect anthropogenic impairment of a wetland. Consequently, despite the many attributes of waterbirds that make them good candidates for bioassessment of non-permanent marshes, before such assessment tools can be recommended we must evaluate the sensitivity of waterbirds to inter-annual climate variability.

My goal is to evaluate the degree to which waterbirds occupying non-permanent marshes are sensitive to anthropogenic disturbance and natural inter-annual climate variability. This will inform whether waterbirds can be used as bioindicators to assess disturbance while remaining insensitive to inter-annual climate variability. Further, I will explore the sensitivity of waterbirds in both the Parkland and Grassland regions and across a range of hydroperiods represented by temporary, seasonal and semi-permanent marsh classes, to evaluate whether natural region or permanence class has a strong influence on the sensitivity of waterbirds to disturbance and inter-annual variability in climate. My specific objectives are to determine 1) if waterbird community composition is sensitive to inter-annual variation in climate, 2) if inter-annual variation in waterbird community composition will differ between the Grassland and Parkland natural regions and 3) if inter-annual variation in waterbird community composition will depend on wetland permanence class; and 4) whether inter-annual variation in waterbird

community composition will depend on the degree of agricultural disturbance affecting the wetland. Note that I expect waterbird community composition to differ between natural regions (see Chapter 2), wetland permanence classes, and different levels of agricultural disturbance, because these factors influence habitat suitability for waterbirds (Paillisson et al. 2002, Baschuk et al. 2012). My real interest is in whether these factors interact with inter-annual variability in climate conditions, namely precipitation and temperature. Most importantly, I am interested in whether the response of waterbirds to disturbance level will differ between sample years, because if waterbird sensitivity to agricultural activity varies year to year, waterbirds will not likely be reliable indicators of wetland condition.

## 3.2. **Methods**

### 3.2.1. *Study area and sampling design*

I carried out my study in the Parkland and Grassland natural regions of Alberta, where agriculture is the dominant land use (Stewart and Kantrud 1970, Ecological Stratification Working Group 1996) due to fertile soils and the favorable number of growing degree-days (Millett et al. 2009). However, industrial and urban development is also present in these natural regions (Beyersbergen et al. 2004, Natural Regions Committee 2006).

The Parkland represents a transition between the Grassland and the Boreal natural regions, possessing a mean annual temperature and growing season length and receiving precipitation intermediate between these two other natural regions (Natural Regions Committee 2006). Climate in the study area functions as a moisture-deficit regime where evapotranspiration exceeds annual precipitation, more so in the Grassland than the Parkland (Beyersbergen et al.

2004, Natural Regions Committee 2006, Millett et al. 2009). The Grassland is the driest and warmest natural region within Alberta; the more pronounced moisture deficit in the Grassland restricts tree growth significantly (Natural Regions Committee 2006).

The Parkland can be characterized as a deciduous forest-grassland mosaic with hummocky uplands and undulating plains, where surficial geology is dominated by un-stratified glacial till. The Parkland region possesses about 10% wetland cover by area. In contrast, the Grassland is characterized as undulating plains underlain with glaciofluvial and glaciolacustrine deposits, and it possesses about 3-7% wetland cover.

In 2014 and 2015, I sampled twenty-four non-permanent marshes within the NP&PR about monthly from May to September. These were evenly distributed among 6 sub-watersheds: 3 sub-watersheds in each of the Grassland and Parkland natural regions (Figure 3-1). Sites averaged 0.94 ha (+/- 0.21 standard error) in size and were spaced a minimum of 3.5 km apart to minimize spatial autocorrelation. Sub-watersheds were selected based on 1) being positioned wholly within either the Parkland or Grassland natural regions; 2) being entirely contained within Alberta's borders; and 3) possessing a glaciolacustrine or glaciofluvial derived surficial geology. Table 3-1 summarizes the mean temperature for the sampling periods and accumulated precipitation for each sub-watershed.

Selected wetlands also spanned non-confounding gradients in agricultural activity (i.e. disturbance) and hydroperiod (i.e. marsh permanence class). Wetland size and class were determined using the provincial wetland inventory and Grassland Vegetation Inventory. Only temporary, seasonal, and semi-permanent marshes were considered, as ephemeral wetlands are not included in Alberta's provincial wetland inventory or managed under the provincial wetland

policy (Government of Alberta 2013). Land cover and disturbance class was derived from the Agriculture and Agri-Food Canada Annual Crop Inventory Data (2015). I categorized sample wetlands a priori on the basis of the percent of natural land covers within a 500 m buffer around each wetland: wetlands were either high (<25% natural cover), medium (25-75% natural cover), or low (>75% natural cover) disturbance. Natural land covers included forest, open water, native grassland and wetland. Due to the level of agricultural activity in both natural regions, where 75% of land is privately owned (Natural Regions Committee 2006, Environment and Sustainable Resource Development 2011), truly pristine reference sites are scarce if they exist at all. Also because of the dominance of agricultural activity in the NP&PR, disturbed sites were primarily located on private property or crown land, whereas some reference wetlands were located in provincial parks.

### 3.2.2. *Field methods*

Bird surveys comprised a visual survey and an acoustic point count survey conducted by pairs of observers, following the methods of Wilson and Bayley (2012). In brief, bird surveys were conducted on two occasions, at each site during the breeding season (May 19<sup>th</sup> –June 24<sup>th</sup>) to account for any variability in seasonal timing of waterbirds using the wetlands. Surveys were restricted to take place between sunrise and 11:00 am because that is when birds call and sing with the highest frequency, following recommendations of the Alberta Biodiversity Monitoring Institute (2012). To account for variability in time of day, the order of site visits was rotated during the second visit (Wilson and Bayley 2012).

Visual surveys were conducted first to avoid flushing birds by entering the wetland. From a pre-determined vantage point with a clear view of the open water, observers surveyed waterbirds using a spotting scope and binoculars for 10 min. They then proceeded to the point count location. Total site size dictated the number of point counts completed and aerial photos were used to select point count locations in advance. Because the study wetlands were nearly all less than 1 ha in area, only one point count was typically necessary and point counts were generally situated in the center of the wetland to minimize edge effects (Alberta Biodiversity Monitoring Institute 2012). In larger wetlands where multiple point counts were warranted, point counts were situated at least 200 m apart and 100 m from any upland, following the protocol devised by U.S EPA. (2002). Point counts comprised one 8 min survey noting all auditory or visual detections of waterbirds. Multiple point counts at the same site were summed, both across point count locations and site visits within year. Identifications were made following the American Ornithologists Union Standard. During acoustic surveys, recordings were taken for QA/QC purposes using a Song Meter SM2+ in 2014 or a Zoom H2N Portable Digital Recorder in 2015. Inclement weather was recognized as a potentially limiting factor (U.S EPA. 2002, Alberta Biodiversity Monitoring Institute 2012). Where feasible, waterbird surveys were conducted during ideal conditions and surveys were deferred on days when wind or rain prevented auditory detection of birds or reduced bird song. Wind speed was determined before each survey using the Beaufort Wind Scale (Appendix 3) following recommendations of Downes (2003), Alberta Biodiversity Monitoring Institute (2012). If wind exceeded a force of 3 (loose paper lifted, small tree branches moving) surveys were suspended until wind died down.

In addition to monitoring birds, we collected information about the abiotic condition of each wetland. Staff gauges were installed at each wetland in May and used to generate a hydrograph based on about monthly visits between May and September.

### 3.2.3. *Climate data*

Climate data were retrieved from the Government of Canada (2015), Alberta Agriculture and Forestry (2015) and Government of Alberta (2015). Six weather stations were chosen to represent each of the sub-watersheds, Figure 2-1 depicts where the weather stations are situated in relation to the sample sites. For each of the six weather stations, accumulated monthly precipitation was calculated using recorded daily precipitation. Climate normals (1981-2010) were only available from certain weather stations, and the locations are also shown on Figure 3-1. Climate normals were used to compare with climate data collected in both sample years in terms of mean monthly precipitation and mean accumulated precipitation for May to September. Historical and recent snow depth data was only available for stations within the Parkland.

Average drawdown was calculated for all sites sampled in 2014 and 2015, and also for subsets of sites to compare differences in drawdown for region, revisited sites and wetland classes. The average was calculated by converting the date that the staff gauge was found dry to the day of year ranging from 1 (representing January 1<sup>st</sup>) to 365 (December 31<sup>st</sup>). Sites that did not drawdown during the sampling period were assigned a drawdown date of 365 (December 31<sup>st</sup>) as they were assumed to remain wet for the remainder of the year (Table 3-4).

#### 3.2.4. *Statistical analysis*

Analysis followed a modified framework proposed by Clarke (1993) for non-parametric analysis of community data. The framework involves 1) displaying community patterns graphically 2) identifying taxa responsible for wetland clustering and 3) testing for significant differences among groups of wetlands. If I find a significant interaction among groups of wetlands I will further explore the nature of the changes graphically. All multivariate analyses were conducted on a Bray-Curtis dissimilarity matrix, as this distance measure ignores joint absences and the comparison between two sampling units is independent of the removal or addition of other sampling units (Clarke and Warwick 1994). Data were  $\log(x+1)$ -transformed before performing analysis to normalize as recommended by McCune (2011) and all rare species occurrences ( $n < 2$ ) were removed.

To determine if waterbird communities were sensitive to changes resulting from natural climatic variability between two consecutive sampling years: 2014 and 2015, I conducted nonmetric multidimensional scaling (NMS) on the Bray-Curtis distances using PC-ORD version 6 (McCune 2011) to display patterns and changes in community composition among sites and to identify species whose abundances were correlated with the community gradients. The NMS ordination was run 50 times with randomized data and 50 times with real data. To visually display the change in community composition related to inter-annual variation in climate, vectors were used to connect the position of sites in ordination space as sampled in 2014 with their position in ordination space as sampled in 2015. Joint plots were used to visualize what waterbird abundances are driving community differences among the sites and between years. A

community joint plot was created by overlaying vectors on the final ordination that represented the strength and direction of correlations between NMS axes and species abundances.

To test whether differences in waterbird community composition between sample years observed qualitatively using NMS joint plots were statistically significant, I used perMANOVA or permutational analysis of variance (Anderson 2001) on the Bray-Curtis dissimilarity matrix with sample year as a random factor. PerMANOVA is essentially a distance-based non-parametric MANOVA with a permutation test to derive a p-value (Peck 2010). Briefly, perMANOVA was chosen because of its flexibility to use with community assemblage data that does not meet formal assumptions of normality that are necessary for use with linear models and because of its ability to partition variance like ANOVA while providing the robustness of non-parametric methods (Anderson 2001).

Where complex interactions may be affecting multivariate responses, multi-factorial perMANOVA can be used as a flexible approach that allows a quantitative examination of these interactions (Anderson 2001). I conducted two-factor perMANOVAs on Bray-Curtis dissimilarity matrices to determine if differences in community composition of waterbirds between 2014 and 2015 occur: 1) between the Parkland and Grassland natural regions, 2) among permanence classes, and 3) among the range of disturbance classes. The first factor was year (random) and the second factor (fixed) was natural region, marsh permanence class, or disturbance level, respectively. Where significant results were found using the multi-factorial perMANOVA's, further NMS ordinations were conducted to graphically display patterns following the above-described method.

To confirm species vector overlays were indicative of changes between years and not reflective of differences in disturbance or class among sites, species abundances were summed per year and compared. Lastly, to quantify the change in sites from 2014-2015 for each region, the difference between position within ordination space in 2014 and 2015 was used a distance and summed for each region. In other words, the distance of the vectors connecting 2014 sites to 2015 sites was calculated for each axis.

### 3.3. Results

#### 3.3.1. General results

Abundance and richness were, on average, very similar between years. In 2015, we saw a mean abundance of 36 individuals per site ( $\pm 3.09$  standard error) and mean richness of 8 species per site, ( $\pm 0.64$  standard error) compared to 2014 where the mean abundance was 34 individuals per site ( $\pm 3.29$  standard error) and richness of 7.2 species per site ( $\pm 0.56$  standard error). Species that showed the largest changes in relative abundances from 2014 to 2015 are Blue-winged Teals (*Anas discors*), Northern Shovelers (*Anas clypeata*), Red-winged Blackbirds (*Agelaius phoeniceus*), Savannah Sparrows (*Passerculus sandwichensis*), Song Sparrows (*Melospiza melodia*), Western Meadowlarks (*Sturnella neglecta*) and Wilson's Phalarope (*Phalaropus tricolor*). Species that decreased in abundance in 2015 were Blue-winged Teals, Northern Shovelers, Wilson's Phalarope and Red-winged Blackbirds whereas Savannah Sparrows, Song Sparrows and Western Meadowlarks increased in abundance.

### 3.3.2. *Hydroperiod changes*

Staff gauges installed in each wetland revealed significant changes in hydroperiod between 2014 and 2015. Average draw down considering all sites is 70.5 days (+/- 18.1 standard error) earlier in 2015. Contrasting the two Natural Regions, 2015 drawdown date was on average 63.0 (+/- 16.9 standard error) days earlier in the Parkland and 128.3 (+/- 13.65 standard error) days earlier in Grassland sites (Table 3-4). The earlier drawdowns dates are mirrored in reduced snowpack and springtime precipitation, although annual precipitation was within the range of climate normals (1981-2010). Snowpack depth ranged from 60%-100% less in 2015 compared to 2014. Both stations had a snow depth of zero in April of 2015 compared to over 20 cm in 2014 and 2013 (Appendix 2). Comparing the six sub-watersheds, May and June precipitation was 48-82% lower in 2015 than 2014, during waterbird surveys.

### 3.3.3. *Waterbird variation across year, region and disturbance class*

The two-factor perMANOVA to test whether waterbird community composition differed between years, between regions, and whether region and year had a significant interaction had p-values of < 0.05 for both main factors and their interaction (Table 3-5). However, the two-factor perMANOVA testing for the effect of year and wetland class and the two-factor perMANOVA testing for the effect of year and disturbance level both found only main factors were significant. I.e., although waterbird community composition did differ among temporary, seasonal and semi-permanent wetland classes and among high, medium and low disturbance classes, the effects of wetland class and disturbance level on waterbird community composition were consistent in 2014 and 2015.

To explore the influence of inter-annual variation on waterbird community composition, I carried out NMS ordination. The final NMS ordination solution for the 24 wetlands possessed 3 significant dimensions with a stress of 16.35 and an instability of <0.00001 after 91 iterations (Figure 3-2). The cumulative variance represented by the final solution was 82%. This solution was varimax rotated (McCune 2002). This is a rigid rotation that aligns the gradient explaining the most variance in the Bray-Curtis distance matrix with the first axis. The result revealed that 42% of the variance in the distance matrix is explained by axis 1, 24% by axis 2 and 16% by axis 3. Although a three dimensional solution was deemed optimal, the third axis explains only marginal portion (16%) of variance in the dissimilarity matrices. On visual examination, the third axis does not help separate high disturbance from low disturbance wetlands, 2014 samples from 2015 samples or by wetland permanence class (Appendix 5). This suggests the variation in community composition described by axis 3 is not related to inter-annual variation or the effects of agricultural activity and therefore it is not described further in this chapter. For further description please refer to Appendix 5. The shift from 2014 to 2015 in ordination space is characterized by a positive correlation with axis 1 and a negative correlation with axis 2. Axis 1 also segregates the regions with Parkland sites associated with a positive axis 1 score and Grassland sites with a negative score. The abundances of Chipping Sparrows (*Spizella passerina*), American Robins (*Turdus migratorius*) and Yellow Warblers (*Setophaga petechial*) are positively correlated with axis 1 and the abundance of Western Meadowlarks is negatively correlated with axis 1. Axis 1 also separates tree-dependent birds and residents from waterbirds that nest on the ground and forage using the probing method. Axis 2 separates high disturbance sites from low disturbance sites. Axis 2 also visually segregates permanence class. Red-winged Blackbirds are positively correlated with axis 2 of the ordination and Savannah Sparrows are

negatively correlated with axis 2. Waterbirds that prefer deeper wetlands (ponds), and who forage by surface dives are positively correlated with axis 2 and grassland obligate species are negatively correlated with axis 2.

The summation of vectors between 2014 and 2015 sites revealed that the Grassland change across all three axes (Table 3-6) was marginally larger (22.79) than the Parkland (21.05). The largest difference between years aligned with axis 1 for the Grassland, whereas the difference between the Parkland was greatest in axis 2 and axis 3.

Because the two-factor perMANOVA revealed a significant interaction between year and region, I conducted separate NMS ordinations on Grassland and Parkland sites to determine which waterbird species are driving the year-to-year community changes within each region.

The final NMS solution for the 12 Parkland sites recommended 3 dimensions with a stress of 13.34, an instability of  $<0.00001$  and was run for 53 iterations (Figure 3-3). The cumulative variance represented by the final solution was 70%, with 38% represented by axis 1, 19% by axis 2 and 13% by axis 3. Axis 3 represents little of the total variance in the dissimilarity matrix and on examination; axis 3 did not separate sites on the basis disturbance level, permanence class, or year. It is not described further in this chapter but is depicted in Appendix 6. Separation of years, disturbance and permanence class is occurring on both axis 1 and axis 2. Again, overlaying vectors representing the correlation between NMS axes and species abundances, the abundance of Blue-wing Teals and Northern Shovelers are negatively correlated with axis 1 and the abundance of Savannah Sparrows is positively correlated with axis 1. Migrant waterbirds, dabblers and waterbirds that prefer deeper wetlands (lake/pond) are positively correlated with axis 1. Killdeers (*Charadrius vociferus*) are positively correlated with axis 2 and Black-capped

Chickadees (*Poecile atricapillus*) are negatively correlated with axis 2. Lastly, axis 2 separates waterbird species who are dependent on trees from marsh obligates and species that build floating nest.

The final NMS solution for the 12 Grassland sites recommended 3 dimensions with a stress of 13.33, an instability of <0.00001 and was run for 46 iterations (Figure 3-4). The cumulative variance represented by the final solution was 67%, with 34% represented by axis 1, 20% by axis 2 and 13% by axis 3. The total variance in the dissimilarity matrix represented by axis 3 is <15% of the total variance and did not segregate sites based on year, disturbance level or permanence class so it is not described further in this chapter but is depicted in Appendix 7. Axis 1 is separating years, disturbance, and permanence class. Overlaying vectors representing the correlation with waterbird species abundances (Figure 3-4b) it is evident that the abundance of Red-wing Blackbirds is negatively correlated with axis 1 and the abundance of Clay-coloured Sparrows (*Spizella pallida*) is positively correlated with axis 1. Axis 1 also segregates foliage gleaners who may be dependent on shrubs from surface diving waterbirds. Blue-winged Teals are positively correlated with axis 2 and American Crows (*Corvus brachyrhynchos*) are negatively correlated with axis 2. Axis 2 separates tree-dependent species from marsh obligate waterbirds and ground nesting species.

### 3.4. Discussion

Waterbirds have the potential to be useful indicators of agricultural degradation due to their sensitivity to agricultural activities, ubiquitous nature, relative ease of sampling and socioeconomic value (Adamus and Brandt 1990). Monitoring tools have been successfully

developed using bird communities to detect disturbance in forest habitats (Canterbury et al. 2000), in shallow open-water wetlands (Wilson and Bayley 2012) and in sagebrush steppe (Bradford et al. 1998). In Chapter 2, I presented evidence that waterbirds in the NP&PR show high potential to be used as indicators because certain assemblages responded predictably to a gradient of agricultural disturbance. The NP&PR, however, has a natural climate cycle that can result in large differences of precipitation between years (Millett et al. 2009) and subsequently large inter-annual variation in hydroperiod. Waterbirds are also sensitive to fluctuations in hydroperiod, and so this temporal variability presents a challenge in using birds as bioindicators in the NP&PR. Changes in bird communities in response to natural variations in climate and hydroperiod may mask the signal of anthropogenic disturbance (Bradford et al. 1998, Euliss and Mushet 2011). For instance, Chin et al. (2014) conducted a long-term study that revealed indicators using marsh specialist and generalist birds correlate with increasing and decreasing lake levels in Ontario. Chin et al. (2014) cautioned against using bird community based indicators when inter-annual variation of water levels is evident because wetlands in dry years may erroneously reflect low quality habitat scores. A major objective of this chapter was to determine whether that sensitivity to agricultural disturbance would be affected by inter-annual variability in climate, potentially compromising any wetland evaluation tools based on the waterbird community.

My perMANOVA tests revealed that waterbird community composition does vary significantly with disturbance level and with inter-annual differences in precipitation; however, there is no significant interaction between differences in waterbirds associated with year and differences in waterbirds associated with disturbance. This suggests that the changes to

waterbird community composition relating to inter-annual variations in climate are independent of variations in community composition attributable to agricultural disturbance. Evidence that variation in waterbird community composition between sample years with differing climate is independent of variation in waterbird community composition associated with agricultural activity is also found in my ordination results. Consequently, it should be possible to identify waterbird based metrics that would respond to changes in agricultural activity but would be insensitive to inter-annual variation, yielding a waterbird-based index of biological integrity for marshes of the NP&PR that could detect changes due to agriculture against a background of climate variability.

#### *3.4.1. Small changes in precipitation yield large changes in waterbirds*

As observed by other authors (e.g., (Euliss et al. 2004, Batzer and Baldwin 2012), variability in the pattern of precipitation had a substantial impact on hydroperiod in our 24 study marshes. Hydroperiod is especially sensitive to snowpack depth, as this is the major water input to most prairie marshes (van Der Kamp and Hayashi 2009). The fact that the annual precipitation amounts in both the Parkland and the Grassland were nearly identical between years (Table 3-2) illustrates how sensitive hydroperiod (and consequently waterbird community composition) are to the timing and pattern of precipitation. Despite a particularly rainy July and August in 2015, a 75% reduction in snowpack and a 56% reduction in May and June precipitation was enough to reduce the average hydroperiod by 21% in the Parkland and 43% in the Grassland from hydroperiods observed in 2014. Consequently, over half of the wetlands had dried up by June in 2015, compared to only 12% of the wetlands drying up by June in 2014.

Bearing in mind that the waterbird breeding season in the NP&PR typically spans May and June (Greenwood et al. 1995, Beyersbergen et al. 2004), the reduction in hydroperiod following low snow pack depths and below average springtime rainfall constitutes a major difference in the amount of breeding habitat available in 2015 compared with 2014. Historically, a significant linear relationship has been found between the number of marshes with ponded water in May and the number of individual waterfowl (Batt et al. 1989, Mitsch 2007, Ballard et al. 2014). Further, waterfowl reproductive success and abundance is directly correlated with the number of wetlands containing water in May (Euliss et al. 2004). It is therefore not surprising that the reduction in hydroperiod I observed in 2015 was correlated with significant differences in waterbird community composition.

Generally, the 2015 sample points occupy a larger area in ordination space than the 2014 sample points, indicating that the dissimilarity among sites is larger in 2015 when conditions were drier. Specifically, in the drier 2015 sampling period, I saw an increase in the abundance of upland species such as the Savannah Sparrow, Song Sparrow, Western Meadowlark and, in the Grassland, Vesper Sparrow, all of which would prefer drawn down marshes to open water. In contrast, Blue-winged Teal and Northern Shovelers were more abundant in the wetter 2014. Northern Shovelers and Blue-winged Teal are both dabbling ducks in the family Anatidae. Most Anatidae form breeding pairs during winter, establish nesting sites in May and prefer temporary and seasonal marshes with high interspersed (Dubow 1996, Rohwer et al. 2002). Swanson and Duebbert (1989) found that Blue-winged Teals and Northern Shovelers are among the most sensitive waterfowl to drought as they respond sooner than other species by either migrating to different geographic areas or shifting to more permanent wetlands in traditional breeding

locations, depending on the severity of drought. The early drawdown of shallow wetlands would reduce their suitability for dabblers. In the Grassland, Willets, as probing shorebirds, prefer breeding in small shallow marshes without robust emergent vegetation which can impede their foraging (Hands et al. 1991). Given that 65% of seasonal and temporary wetlands sampled were dry by the end of June 2015, compared to only 17% in June 2014, the observed replacement of obligate wetland shorebirds, surface divers and dabblers with grassland species in 2015 might be attributed to the greatly decreased available aquatic habitat for the latter half of the breeding season. Because of waterbirds' inherently mobile nature they are able to re-locate very easily to more suitable habitat (Euliss et al. 2004). Batt et al. (1989) suggest that strong competitors residing in the NP&PR will show a great deal of variation during climate fluctuations because they are able to re-locate fairly easily and out-compete less territorial species. Overall, my results seem to be in line with this pattern as sites showed a sharp decrease in abundances of Blue-Winged Teal and Northern Shovelers in both regions and Red-winged Blackbirds in the Grassland; all of which can be known to be opportunistic, territorial species (Yasukawa and Searcy 1995, Dubowy 1996, Rohwer et al. 2002).

A shift in hydroperiod will not only affect the availability of breeding habitat, it will influence abiotic features that subsequently define the composition of wetland plant, invertebrate, and vertebrate communities (Euliss et al. 2004, Batzer and Baldwin 2012). Changes in community composition due to variable precipitation are generally attributed to bottom-up effects such as food and habitat availability (Murkin et al. 1997, Paillisson et al. 2002). It is worth noting; however, that Fletcher (2003) concluded that top-down effects, or predators, also affected bird species during drought years. As water levels decrease, predation increases,

because of reduced vegetative cover, and reproductive success of nesting species declines (Fletcher 2003). My results may support Fletcher's (2003) findings in regards to consistent abundances of Red-wing Blackbirds in the Parkland despite reductions in hydroperiods. However, I found a reduced abundance of conspicuous ground nesting species in 2015, particularly in the Grassland. For example, I observed fewer Blue-wing Teals and Northern Shovelers in both regions, with the greatest reduction in the Grassland. Ground-nesting sparrows or songbirds did not decrease, and an increase was observed in some species, such as Western Meadowlarks and Clay-coloured Sparrows. The decrease in conspicuous ground nesting species could be attributed to reduced vegetative cover due to drought and consequently reduced cover to avoid predators. In terms of the decrease in nesting waterfowl species, my results are also consistent with Murkin et al. (1997). Murkin et al. (1997) conducted a 10-year experimental study of a delta marsh where he manipulated water levels to mirror natural fluctuation. During initial drawdown years, general avian use and nesting was limited but waterfowl and shorebirds were observed foraging on newly exposed substrate (Murkin et al. 1997). During the second year of a drawdown (dry), dabbling duck nesting increased as a result of the increased vegetated cover (Murkin et al. 1997). Murkin et al. (1997) note that the results may be influenced by the immediate proximity of a permanent wetland and that in most settings waterbirds would have to re-locate during drought years. But, this study opens an interesting question as to how the waterbirds will respond in the year following a dry year. If waterbirds only shifted to more permanent wetlands in the same vicinity of traditional breeding grounds as Swanson and Duebbert (1989) found, the year following a drier year may see an increase in nesting waterbirds as they are able to resume traditional breeding grounds for nesting.

### 3.4.2. *Waterbirds vary based on region, wetland permanence class and disturbance*

In addition to community composition differences between years, waterbird composition varied with natural region. I attribute this to differences in the abundance of woody vegetation. The Parkland has more tree and shrub cover surrounding wetlands that can support foliage gleaners, tree nesters, fruit eaters and other birds dependent on woody vegetation (Ecological Stratification Working Group 1996, Natural Regions Committee 2006). For instance, tree dwelling species such as American Robin and Black-capped Chickadee are associated with the Parkland, whereas shore-line dwelling species, such as Marbled Godwit are associated with the Grassland sites, which supported more probers, dabblers, and ground nesters.

Wetland permanence class was also a significant factor in shaping waterbird community composition. It is based on hydroperiod but is identifiable using vegetation communities (Stewart and Kantrud 1970), as robust emergent vegetation is replaced by sedges and then flood tolerant grasses as hydroperiods shorten. Class might be especially important in the Parkland, where willow and alder shrubs are common in temporary marshes but not seasonal and semi-permanent. This importance is evident as tree dwelling species such as Black-capped Chickadee and Red-breasted Nuthatch are associated with temporary marshes and can be attributed to the occurrence of shrubs. In the Grassland, surface diving waterbirds require greater water depths than dabbling waterfowl and are appropriately associated with semi-permanent marshes. Savannah sparrows are associated with temporary marshes in both regions, likely as a result of their preference for finer grasses (Rodewald 2015).

On visual inspection, my results indicate that marsh permanence class may be confounded with disturbance. This could be attributed to the preferential loss of temporary and

seasonal wetlands that typically occurs (Serran 2015). Semi-permanent wetlands are comparatively harder to cultivate over under normal climate conditions because they have deeper water and longer hydroperiods compared to seasonal or temporary marshes (Bartzen et al. 2010). Thus, wetlands that do remain in a highly disturbed landscape are most likely to be semi-permanent. If multiple temporary and seasonal marshes are cultivated in a small area, the water that had previously been collecting there could accumulate into and begin to form a larger semi-permanent marsh.

Of most consequence to the question of whether waterbirds could be used as useful indicators of marsh condition, I found that waterbird community composition also differed significantly among high, medium and low disturbance wetlands. Namely, as observed in Chapter 2, disturbed marshes in the Parkland supported more Red-winged Blackbirds and Mallards and reference marshes had more Yellow Warblers and Red-eyed vireos. In the Grassland, disturbed marshes also supported more Red-winged Blackbirds and reference marshes supported a mixture of grassland sparrows, waterfowl and shorebirds. This reflects a shift in traits from more sensitive species with specific niches to more opportunistic generalist species dominating. Disturbance alters the structure and function of natural wetlands by altering hydrology, increasing siltation due to runoff and physically removing vegetation surrounding wetlands with tillage, cropping and trampling from cattle grazing (Guntenspergen et al. 2002). The destruction of surrounding upland habitat can reduce suitable nesting cover for many waterbirds (Batt et al. 1989). Also, tillage during dry years eliminates strong-stemmed perennial plants and these are replaced in wet years by weak-stemmed annals that are not robust enough to support most nests (Kantrud and Stewart 1984). Therefore it is not surprising that waterbird

assemblages vary across the differing disturbance levels as disturbance physically alters the habitat available and usable to waterbirds.

### *3.4.3. Inter-annual climate variation interacts with region but not disturbance and permanence class*

The significant association between agricultural disturbance and waterbird community composition suggests that waterbirds are good candidates for biological indicators of agricultural impacts. Yet, the significant association between waterbird community composition and year raises concern that the signal of agricultural disturbance could be confounded by variation in the waterbird community stemming from natural inter-annual variation in precipitation and hydroperiod. The literature yields mixed conclusions on the potential of waterbirds to serve as wetland bioindicators in light of their sensitivity to hydroperiod and climate variability. Euliss and Mushet (2011) found that plant-based IBI scores were inconsistent throughout a span of 4 years as a result of spatial and temporal variability and conclude that any IBI development in the Prairie Pothole Region (PPR) will face major challenges. In contrast, Wilson et al. (2012) were able to develop bird-based wetland monitoring tools for permanent marshes in Alberta's NP&PR despite the sensitivity of restored, created and disturbed permanent wetlands to climate variability by selecting metrics that were insensitive to climate differences. Similarly, Chin et al. (2014) found that waterbirds were sensitive to variable hydrology, yet they were also able to produce an applicable bioassessment tool in Great Lakes coastal wetlands. My two-factor perMANOVA found no significant interaction between the year and disturbance level factors. Thus, I conclude that in non-permanent marshes in Alberta's NP&PR, the influence of agricultural disturbance on waterbird community is similar year to year. When Parkland and

Grassland regions are treated separately, my ordination results support this conclusion: variation in the extent of agricultural activity within 500 m of each marsh is aligned with an ordination axis orthogonal to the axis with which community composition changes between years. In other words, the change in waterbird community composition associated with disturbance is somewhat independent of the change due to inter-annual variation in hydroperiod. Consequently, it should be possible to identify metrics based on the waterbird community that are sensitive to agricultural activity, but relative insensitive to inter-annual variability in precipitation. Although caution must be used in metric selection to ensure that any sensitivity to climate is mitigated.

Similarly, I found no significant interaction between the differences in community composition of waterbirds in wetlands of differing permanence class and the differences in waterbirds between sample years. One interpretation is that the reduced snow pack and springtime precipitation in 2015 caused changes in waterbird community composition that affected waterbirds in all wetland permanence classes similarly. Water level was reduced and drawdown was increased in all wetland classes, such that in semi-permanent, seasonal and temporary marshes, upland birds became more common and shallow divers and dabblers became less abundant. This is somewhat surprising, as work by Johnson et al. (2010) suggested that in dry years semi-permanent wetlands would be disproportionately affected, as temporary and seasonal marshes would already typically be dry before evapotranspiration rates peak in late summer. Seasonal and temporary marshes drawdown every year and their hydroperiod is highly dependent on snow melt and spring precipitation, whereas semi-permanent marshes only drawdown in drought years (Stewart and Kantrud 1970). Consequently, I expected that waterbird communities relying on semi-permanent wetlands would respond proportionately

more to changes in habitat availability because waterbirds relying on semi-permanent marshes are not so accustomed to variable drawdown timing. I did observe greater drawdown of semi-permanent marshes: in 2014 no semi-permanent marshes went dry during the sampling period but in 2015 40% dried out entirely. Thus, my results indicate that semi-permanent wetlands may function more similarly to seasonal and temporary wetlands in dry years than in normal or wet years. However, I saw no greater change in waterbird community composition in semi-permanent marshes than I did in other marsh permanence classes studied. Nonetheless, these results are positive for an assessment tool that can be applied across multiple disturbance and wetland scales because it suggests that results in dry years will stay consistent within wetland class and disturbance.

The only significant interaction with year that I observed, based on my two-factor perMANOVAs, was between the Natural Region and Year, meaning the magnitude of inter-annual change in waterbird community composition differs between the Parkland and the Grassland. The ordination combining both regions reveals greater inter-annual differences in waterbird community composition among sites situated in the Grassland natural region than in the Parkland. Further, the nature of the changes in composition of waterbirds differs between the regions (Fig 3-3 and 3-4). Both regions supported fewer Blue-wing Teals and more Savannah Sparrows in 2015, the drier year. There was a large decrease in the abundance of Willets and an increase in Vesper Sparrows in the Grassland in drier 2015, compared with an increase in abundance of Song Sparrows and Yellow Warblers in the Parkland. Because both regions support different communities of waterbirds, it is not surprising that the shift in communities as a result of inter-annual climate variation is different. Generally, the changes in species reflect the

differences between regions in terms of available habitat. Vesper Sparrows are habitat generalists but prefer grassland habitats and Willets occur in shallow (temporary) wetlands with sparse or fine vegetative cover, such as grass (Lowther et al. 2001). Both these species are unlikely to occur in the Parkland. In contrast, Song Sparrows and Yellow Warblers are both shrub nesting species so are more likely to occur in the Parkland where shrubs are common.

Based on my results, metrics can easily be selected that are sensitive to disturbance but insensitive to inter-annual variation. However, metrics are best identified by treating Parkland and Grassland separately. For instance, relative abundance of Sprague's Pipit, Clay-coloured Sparrow and Western Meadowlark are indicative of low disturbance in the Grassland, whereas Mallard, Red-wing Blackbird, and Horned-lark are associated with high disturbance sites. In contrast, Yellow Warbler and Black-capped Chickadee are indicative of low disturbance wetlands in the Parkland, whereas Killdeer, Lesser Yellowlegs, and Red-wing Blackbird are indicative of high disturbance sites in the Parkland. Note that the utility of Red-wing Blackbirds is only evident when Parkland and Grassland sites are examined separately, as when natural regions are combined (Fig. 3-2); they appear strongly sensitive to inter-annual variation. Another example is that Yellow Warblers appear sensitive to inter-annual variation in the Grassland, but orthogonal to it in the Parkland. By selecting metrics so that they that are insensitive to climate variation, seamless comparison of wetland condition between wet and dry years would be possible, but appropriate metrics only become evident when natural regions are treated separately.

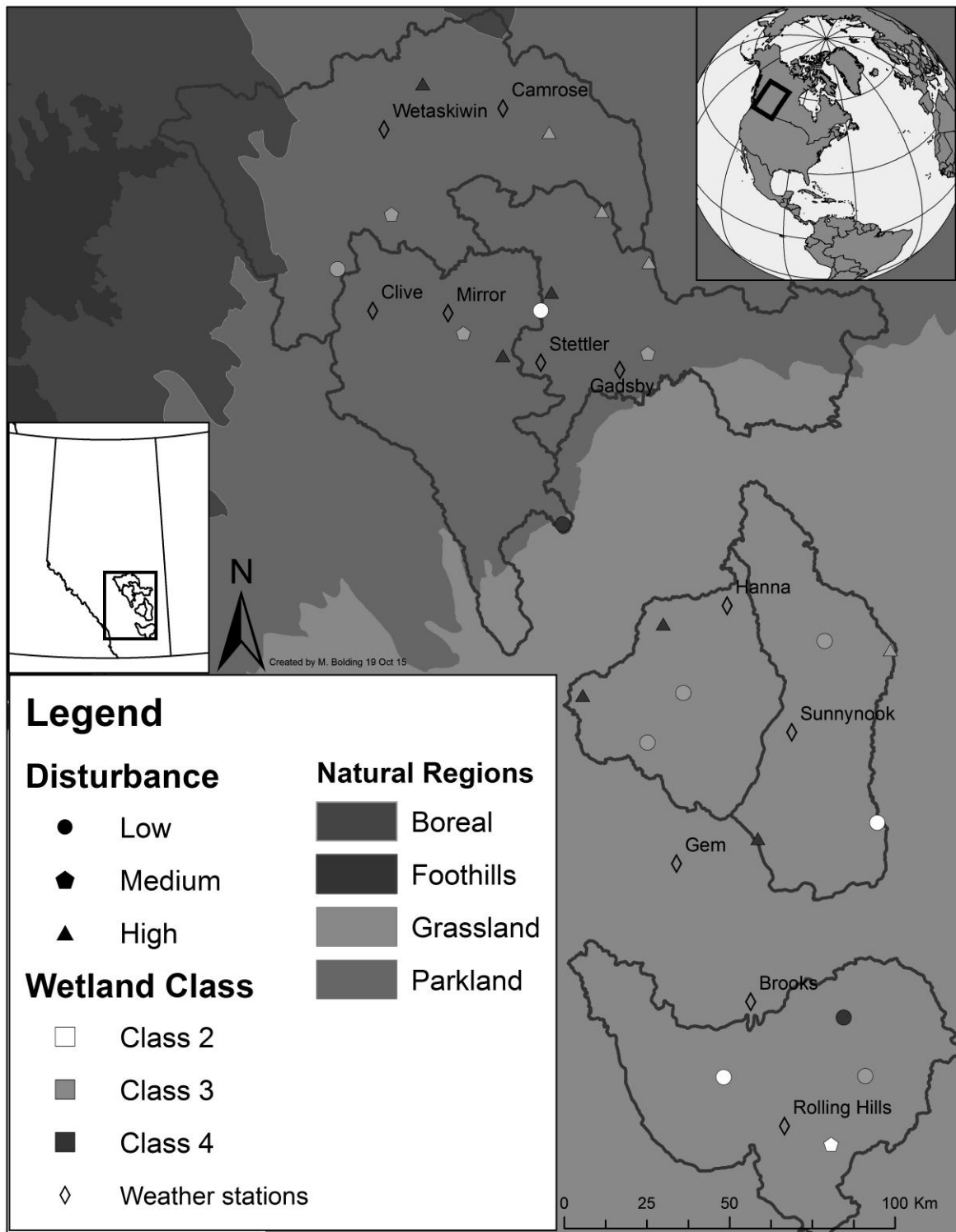
#### *3.4.4. Limitations and implications of findings*

My two-year study indicates waterbird composition is responsive to even small inter-annual differences in total annual precipitation. Perhaps because marshes in the NP&PR are so sensitive to the timing of precipitation in terms of their hydroperiod, which is an important factor influencing waterbird community composition. Although the effect of inter-annual variations on waterbirds may differ between natural regions, it appears consistent across wetland permanence classes and, most importantly, across a gradient in agricultural disturbance. My study captures the natural variability in precipitation that we expect year to year in the NP&PR. It does not reflect incidences of extreme flood or drought. In fact, on an annual basis 2015 and 2014 saw close to the same precipitation (Government of Canada 2015), the difference in wetland drawdown dates was a result of reduced snowpack depth and springtime precipitation. A longer term data record is necessary to confirm that waterbird community changes related to agricultural disturbance remain orthogonal to changes related to altered hydroperiods under more extreme conditions. Despite some limitations due to the relatively short duration of the study and a limited sample, I am confident that waterbirds retain high potential as bioindicators of agricultural disturbance that would be repeatable and yield consistent rankings against a background of naturally varying climate.

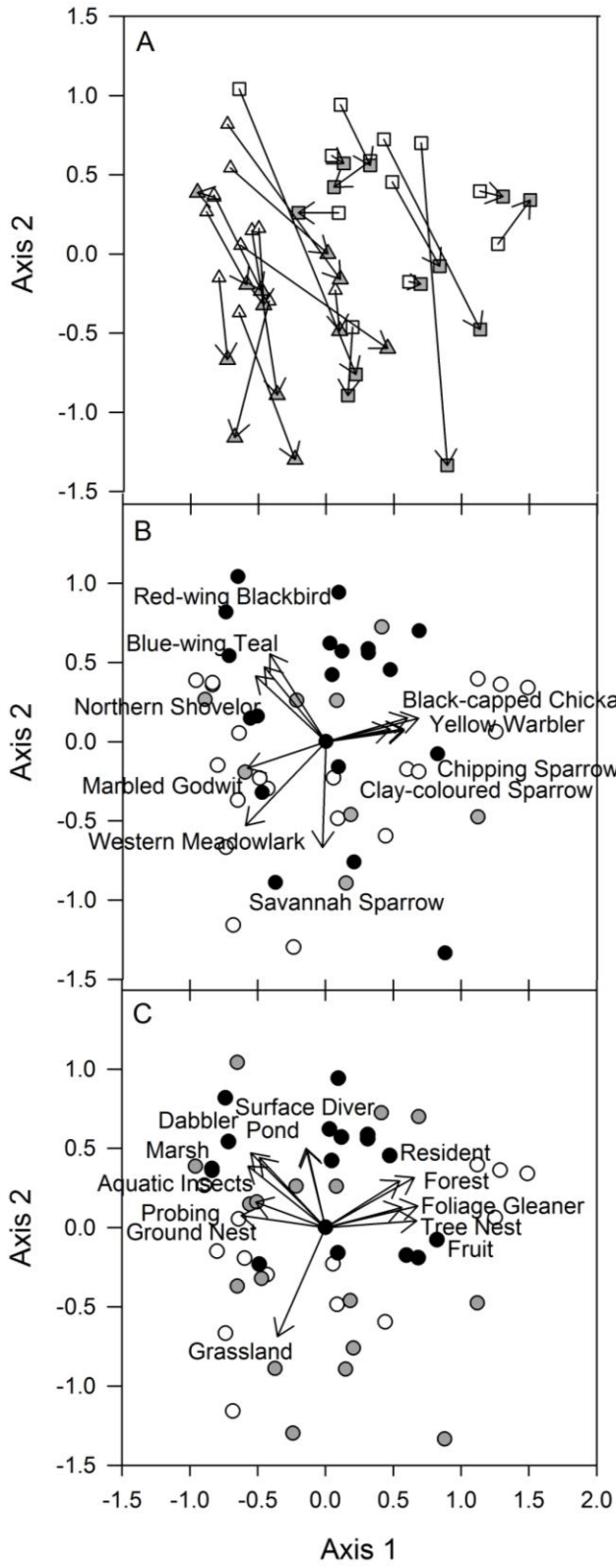
Inter-annual fluctuations in water levels are natural and necessary for wetlands to develop diverse and structurally complex vegetation that can support high biodiversity and waterbird productivity (Murkin et al. 1997). However, this inter-annual variability may be the crux of the issue surrounding the challenge of developing a successful monitoring tool for these marshes, especially as climate change is predicted to increase climate variability in many areas. Global

and downscaled regional climate models predict temperature increases ranging from 2-5 degrees Celsius with only slight increases in precipitation, resulting in shortened hydroperiods that will eventually reduce wetland area in the NP&PR (Johnson et al. 2010, Schneider 2013). Overall, there will be many fewer wetlands within the landscape and wetlands that remain will have shorter hydroperiods (Millett et al. 2009, Schneider 2013, Steen et al. 2014). Fortunately, my results demonstrate that although waterbird community composition is clearly sensitive to variation in climate, it appears that the types of changes in composition provoked by inter-annual variation in climate are largely orthogonal to changes that occur in response to agricultural disturbance. Waterbird community composition differed with natural region, disturbance level and wetland class, but the only significant interaction was between natural region and year. Thus, it should be possible to select region-specific metrics that are sensitive to agriculture, despite the noise of natural inter-annual variation and even the predicted increase in climate variability projected by climate change models. The selected metrics, with consideration, have the potential to comprise a waterbird based monitoring tool that is indicative of overall wetland condition and insensitive to inter-annual climate variability.

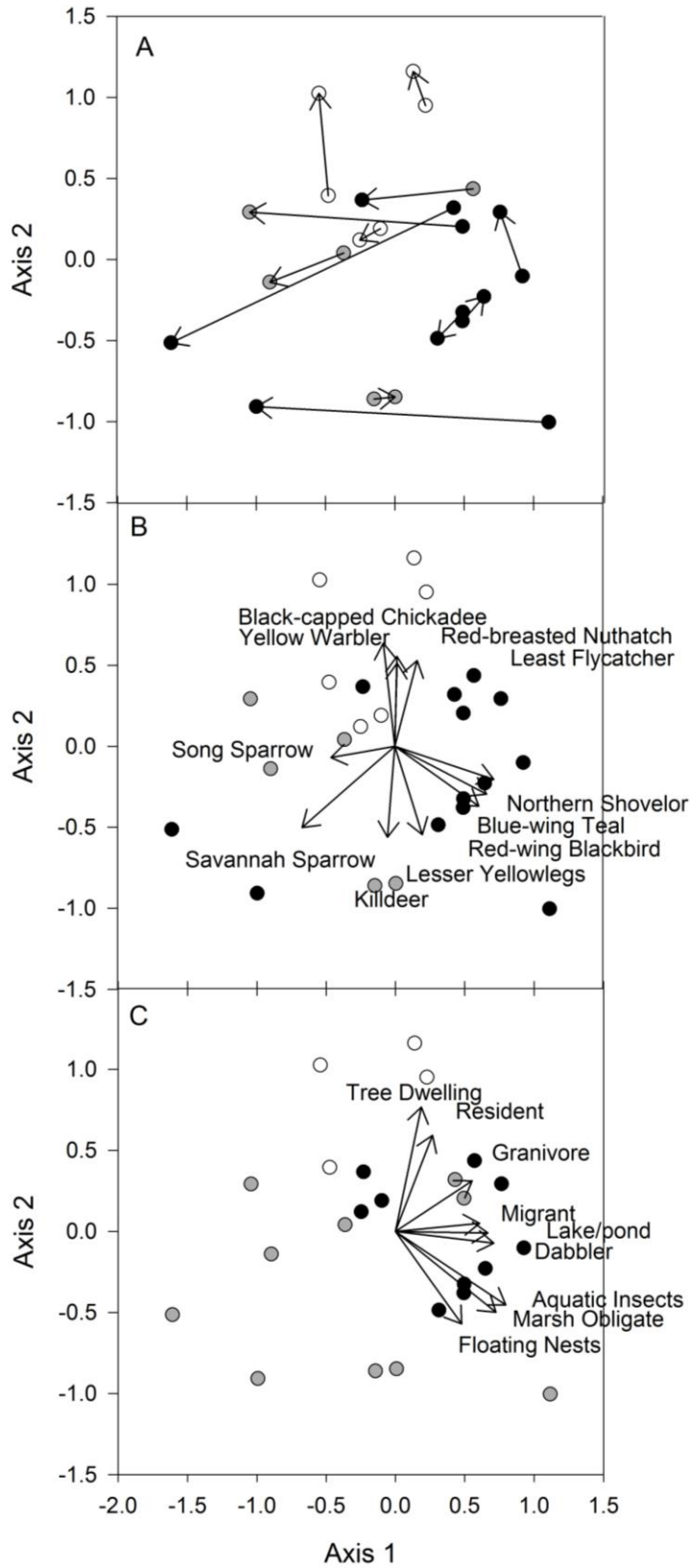
3.5. Figures and Tables



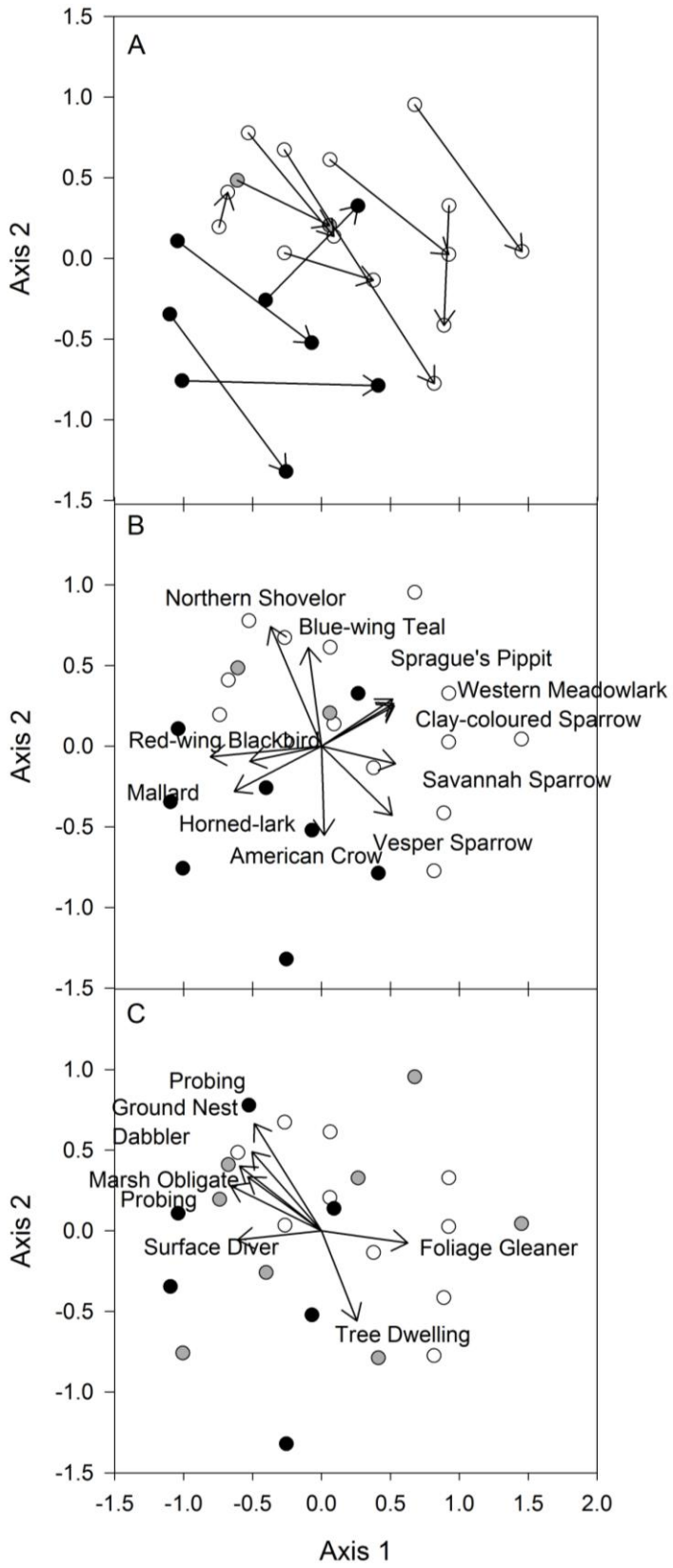
**Figure 3-1: Map of 24 sample sites.** The sample sites are coded based on wetland class; circles are class 2, squares are class 3 and triangles are class 4. Sub-watersheds are overlain over their respective natural regions. The empty diamonds represent the weather stations that climate data was retrieved from. Climate normals (1981-2010) were retrieved for Brooks and Stettler, and precipitation data from sample years was retrieved from the other nine weather stations depicted. Clive and Gadsby stations were used to determine snow depth in the springtime.



**Figure 3-2: Ordination of all sites.** Joint plot of wetlands positioned in species space by non-metric multi-dimensional scaling ordination. (A) Sites are coded by year, white represent 2014 data; grey are 2015 data. Triangles are Parkland sites and squares are Grassland. Vectors represent the shift in the position of each site in species-space from 2014 to 2015 (B) Coded by disturbance, white <24% non-natural cover, grey 25-75% non-natural cover and black >75% non-natural cover and vectors represent the correlation between waterbird taxa and ordination axes. (C) Coded by marsh permanence class, white represents class II, grey is class III, black represents class IV and vectors represent correlation with functional traits. All vectors represented have Pearson's correlation coefficients > 0.2 with at least one NMS axis.



**Figure 3-3: Ordination of Parkland sites.** Joint plot of wetlands for the Parkland sites positioned in species space by non-metric multi-dimensional scaling ordination. (A) White circles represent 2014 data; grey circles are 2015 data, vectors represent the shift in species composition in identical sites from 2014 to 2015 (B) Coded by disturbance, white <24% non-natural cover, grey 25-75% non-natural cover and black >75% non-natural cover and vectors represent the correlation between waterbird taxa and ordination axes. (C) Coded by marsh permanence class, white represents class II, grey is class III, black represents class IV and vectors represent correlation with functional traits. All vectors have Pearson's correlation coefficients >0.250 with at least one NMS axis. Note that whereas disturbance levels are mainly segregated along axis 2 (panel C), inter-annual differences in waterbird community composition are primarily along axis 1 (panel A), indicating that the manner of change in community composition associated with agricultural activity operates independently of the changes in community composition associated with inter-annual variation.



**Figure 3-4: Ordination of Grassland sites.** Joint plot of wetlands for the Grassland sites positioned in species space by non-metric multi-dimensional scaling ordination. (A) White circles represent 2014 data; grey circles are 2015 data, vectors represent the shift in species composition in identical sites from 2014 to 2015 (B) Coded by disturbance, white <24% non-natural cover, grey 25-75% non-natural cover and black >75% non-natural cover and vectors represent the correlation between waterbird taxa and ordination axes. (C) Coded by marsh permanence class, white represents class II, grey is class III, black represents class IV and vectors represent correlation with functional traits. All vectors have Pearson's correlation coefficients >0.250 with at least one NMS axis. Note that the direction of segregation of high (black) and low (white) disturbance sites in panel C is orthogonal to the direction of segregation of 2014 and 2014 sites in panel A. This indicates that the change in community composition associated with agricultural is occurring independently of the changes associated with inter-annual variation.

**Table 3-1: Monthly precipitation compared with Monthly Normal (1981-2010)**

**precipitation.** Precipitation in 2014 is close to normal with the exception of the Grassland experiencing higher than normal precipitation in August. 2015 is much lower in May and June for both regions and above normal in August.

Date	Parkland				Grassland			
	May	June	July	August	May	June	July	August
Normal (1981-2010)	51.9	85.0	94.3	61.0	42.8	68.0	34.4	41.8
2014	30.7	96.9	62.5	68.3	23.3	80.5	31.3	119.0
2015	12.4	44.3	68.2	101.1	4.2	41.5	31.8	109.8

**Table 3-2: Sampling period accumulated precipitation.** The accumulated precipitation (mm) during sampling period (May-September) for natural regions (Parkland or Grassland) and their respective sub-watersheds.

Year	Parkland			Grassland		
	05FA	05FC	05CD	05CG	05CH	05BN
2014	220.8	258.4	189.1	260.4	203.1	220.4
2015	148.9	226.0	262.5	213.5	165.9	104.6

**Table 3-3: Total number of dry wetlands.** Wetlands that were dry at the staff gauge per region at the end of each month.

Year	Parkland					Grassland					Total
	May	June	July	August	Total	May	June	July	August	Total	
2014	0	1	1	5	7	0	2	1	2	5	12
2015	1	4	0	2	7	5	4	2	0	11	18

**Table 3-4: Average draw down in wetlands.** Calculated by converting date to day of year. Sites that remained inundated throughout the sampling period (May-September) were assigned a draw down date of 365. SEM=Standard Error and STDEV= Standard deviation of the data set.

Subset	N	2014				2015			
		Date	Day	SEM	STDEV	Date	Day	SEM	STDEV
All Sites	24	2014-10-14	287.00	16.65	81.57	2015-06-27	216.50	19.56	95.82
Parkland	12	2014-10-24	297.00	15.62	76.51	2015-08-22	234.04	18.09	88.62
Grassland	12	2014-10-22	295.29	17.51	85.76	2015-06-15	166.96	9.79	47.95
Class 4	7	2014-12-31	365.00	0.00	0.00	2015-10-09	282.71	39.49	104.49
Class 3	9	2014-10-06	279.56	27.68	83.05	2015-08-04	216.67	30.16	90.47
Class 2	8	2014-08-15	227.75	21.67	61.29	2015-06-07	158.38	5.07	14.34

**Table 3-5: Results of two-factor perMANOVA tests.** Conducted to determine if significant changes between years and among treatments exist. A p-value of < 0.05 is considered a significant result.

Model	Source	d.f.	MS	Psuedo-F	P-value
Bird community composition = Year + Region + Year x Region	Year	1	0.8055	3.7840	0.0004
	Region	1	1.6322	7.6678	0.0002
	Year x Region	1	0.3973	1.8665	0.0358
Bird community composition = Year + Disturbance + Year x Disturbance	Year	1	0.8055	3.3675	0.0002
	Disturbance	1	0.7488	3.1304	0.0006
	Year x Disturbance	1	0.2391	0.5114	0.9234
Bird community composition = Year + Class + Year x Class	Year	1	0.7277	3.0491	0.0008
	Marsh Class	2	0.4964	2.0928	0.0020
	Year x Marsh Class	2	0.1063	0.4483	0.9932

**Table 3-6: Total change in ordination space.** The absolute distance between each coordinate was calculated and summed for each region to quantify the change in each region explained by each axis.

Region	Axis 1	Axis 2	Axis 3	Sum
Grassland	8.50	7.48	6.82	22.79
Parkland	5.88	8.15	7.02	21.05

#### 4. Synthesis

Despite the growing concern for the health of ecosystems and the greater awareness of the importance of wetlands in the NP&PR (Northern Prairie and Parkland Region), wetlands remain under threat (Zedler and Kercher 2005, Bartzen et al. 2010). The wetlands in the NP&PR have already suffered high rates of loss and degradation, mainly due to agricultural activities (Beyersbergen et al. 2004, Bartzen et al. 2010) and the intensification of agriculture is threatening what wetlands remain (Schindler and Donahue 2006, Rashford et al. 2011). In addition to human-derived stressors such as agriculture, changes in climate can have an impact on the condition of wetlands.

Climate change introduces even more challenges for wetlands in the NP&PR, particularly for non-permanent marshes (i.e. ephemeral, seasonal, temporary and semi-permanent marshes, *sensu* Stewart and Kantrud, 1970). Non-permanent marshes have cyclical hydrology and shortened hydroperiods compared to permanent marshes. This means non-permanent marshes are typically dry during some parts of the year (Euliss et al. 2004) making them easier to drain or completely farm over (Bartzen et al. 2010). As a result of climate change and increasing ambient temperature, the growing seasons are anticipated to increase in length. Presently, in Alberta the growing season is shorter than other parts of the country, limiting the different types of crops that are viable (Schindler and Donahue 2006). If the growing season becomes longer, areas that were previously too costly to farm may become feasible to plant with higher yielding crops such as corn, or areas that are currently pasture may be converted to crops (Rashford et al. 2011). With increases in viable crop types, agriculture will intensify, in cropping distribution and labor intensity, at increased rates.

In addition to the potential changes climate could drive in agricultural systems, it is not clear how marshes will respond to increasing drought and deluge cycles that are predicted as a result of climate change (Johnson et al. 2005, Millett et al. 2009). Because non-permanent marshes are almost entirely dependent on precipitation inputs (Euliss and Mushet 1996), an increase in droughts or floods will have a proportionally greater effect on them compared to more permanent marshes. Increased agriculture coupled with reduced hydroperiods due to increases in droughts could lead to extensive losses of non-permanent wetlands that waterbirds rely upon.

Non-permanent marshes are under the greatest threat from agriculture and climate change, but work in the NP&PR has focused almost exclusively on the larger more, permanent systems. Current wetland inventory tools are suited to detecting wetlands much larger than typical non-permanent marshes and are therefore too coarse to accurately assess the loss of non-permanent marshes (Serran 2015). The small size and isolated nature of non-permanent wetlands though, is part of what makes them especially important to waterbirds because waterbirds depend on small, shallow wetlands to provide defensible breeding habitat (Batt et al. 1989).

The goal of my thesis was to characterize the relationships between waterbird community composition in non-permanent marshes in the NP&PR and the extent of agricultural activity in the surrounding landscape. I also examined the sensitivity of this relationship to inter-annual climate variation and sought elements of the waterbird community indicative of land use that were relatively insensitive to climate variability. These goals combined to allow me to evaluate the potential of waterbirds to serve as robust bioindicators of agricultural disturbance. Having an understanding of how these systems currently function will allow their protection in

the future and mitigate losses. It is increasingly important that the general public, farmers, managers and government understand which wetlands to prioritize.

#### **4.1. Research Findings**

In the 1<sup>st</sup> chapter of this thesis I set the context for non-permanent marshes in the NP&PR and describe the current and future threats. I also outlined the need for characterization and further understanding of waterbird composition in non-permanent marshes. I described how this information is necessary in the development of assessment and monitoring tools that will facilitate the protection and conservation of these understudied marshes. The remainder of my thesis addresses these needs.

In chapter 2, I built upon the work completed by (Wilson 2012) in more permanent systems, and investigated sensitivity of waterbirds to agriculture and characterized the community composition within non-permanent marshes spanning a gradient of disturbance and marsh permanence class. I found that variation in waterbird community composition was associated with both natural region and the level of agriculture in the surrounding landscape. My results indicate that six distinct assemblages of waterbirds exist and are best predicted by a combination of site-level factors and landscape-level factors, particularly forest cover because it segregates Grassland and Parkland sites. Results indicate that as agriculture intensifies wetlands will shift to support limited assemblages and assemblages reflective of low disturbance will become rarer.

In Chapter 3, I evaluated the sensitivity of waterbirds to inter-annual climate variability. I found that even a shift in just the timing of precipitation, not even the annual amount, can have

a large impact on hydroperiod and consequently a significant effect on waterbird community composition. The effect of precipitation differences is only interpretable when the Grassland and Parkland sites are considered separately, because there was also a significant interaction between natural region and year. However, there was no significant interaction between year and disturbance level, indicating that metrics can be selected based on the waterbird community that are sensitive to disturbance from agriculture, but insensitive to inter-annual variation, at least within normal bounds. An understanding of the behavior of metrics under extremes of drought and flood requires a longer monitoring period.

#### **4.2. Implications and Significance**

Wetland management is lacking in Alberta, even with the recent release of the new Alberta Wetland Policy. In the policy, evaluating current wetlands is based off the understanding that some wetlands provide more functions and benefits than others through the amount of relative wetland value which is derived from five functional groups; 1) biodiversity and ecological health; 2) water quality improvement; 3) hydrologic function; 4) human uses; and 5) relative abundance. Using these five functional groups, wetlands are compared, scored and categorized into one of four wetland value categories that rank the relative importance of each wetland (Government of Alberta 2013). This strategy will rank non-permanent marshes very low and favor more permanent wetlands. This function-based evaluation is misleading because non-permanent marshes are just as important, if not more important to migrating waterbirds. My results indicate that non-permanent marshes are being heavily used by both migrating and resident waterbirds. Furthermore, the policy follows an “avoid, minimize, replace” strategy that allows restoration and creation of wetlands to offset permitted losses. In order to effectively

monitor the condition of restored and created wetlands as part of the replacement strategy assessment and determine the quality of wetlands, it is necessary to first understand how agriculture influences waterbird communities in natural wetlands. The findings of my thesis contribute to understanding the influence agriculture has on waterbirds across a gradient, from reference to highly disturbed, meaning benchmarks can be set for waterbird habitat that is being provided by reference wetlands. These benchmarks can be applied before mitigation, restoration, or compensation so that efforts can be evaluated to determine how successfully habitat has been restored based on the waterbird community that the wetland is supporting.

The Alberta Wetland Policy also considers the Grassland and Parkland regions as one unit, or the “White Zone” of Alberta (Government of Alberta 2013). Wetland evaluation tools are anticipated to be applied broadly over the entire White Zone. My results indicate that the Grassland and Parkland show considerable variation in terms of waterbird community composition and should not be considered one cohesive unit. It is not feasible to develop evaluation tools that cover the entire province; rather, they need to be developed for each region separately to reflect differences in habitat, climate and subsequently waterbirds. Realistically, more years of data are needed to make informed decisions because inter-annual climate variability between 2014 & 2015 was only marginal.

Results are positive for applications in bioassessment but indicate that shifts in waterbird species within disturbed landscapes are occurring. Generally, highly impacted sites are seeing an increase in common, habitat generalists. The NP&PR is studied highly because of the high percentages of waterfowl that breed in the region. Waterfowl are of interest as game birds and shifts in communities as a result of increasing agriculture could affect the distribution of popular

game birds. Some species that are sensitive to agricultural are important to hunters such as Northern Pintails and Blue-winged Teals, and if agriculture continues to grow rapidly, then sensitive species of value to hunters will continue to decline in abundance and the value of wetlands for recreational use will decline. Certain bird species are preferred not only by hunters, but bird watchers tend to value rare species over common species that can be seen in less specialized habitats. If non-permanent marshes cease to provide unique habitat that is used by a variety of shorebirds, waterfowl and songbirds, their appeal for bird watching also decreases.

Habitat restoration is a growing field and with the implementation of the Alberta Wetland Policy, the restoration of altered wetlands and creation of new wetlands will remain part of the requirements when wetland destruction cannot be avoided. My results can be used by restoration practitioners, such as Ducks Unlimited, to create and restore non-permanent wetland habitat effectively. I found that landscape and site-level characteristics combine to determine what assemblages of waterbirds will be at a wetland. With that in mind, restoration should focus on areas where both scales can be addressed. For instance, it is not worthwhile to create excellent site-level habitat in an area where the landscape is highly disturbed, because waterbirds select habitat on both of these scales. Significant differences in community composition were found among marsh permanence classes, implying restoration should focus on a range of permanence classes to ensure that the availability of habitat for a range of species is met. Similarly, vegetation at the site scale should be reflective of the natural region. For example, if restoration is being conducted in the Grassland, robust emergent and woody vegetation should be avoided to reflect the natural characteristics of the landscape and the resulting unique waterbird composition that is present.

Farmers rely on their land for their livelihood, and reducing the impact agriculture has on non-permanent marshes will benefit the farmer as much as it benefits the wetland. Plowing through non-permanent marshes will disrupt the ability of a wetland to provide ecosystem services such as flood mitigation and groundwater recharge. Undisturbed or natural soils are typically highly structured, containing numerous macropores provided by decaying roots, fractures and animals burrows; all of which contribute to increased infiltration to underlying till (van Der Kamp and Hayashi 2009). When land is cultivated it destroys the macropores and creates a layer of less permeable soil, effectively reducing infiltration capacity (van Der Kamp and Hayashi 2009). Since cultivated land has reduced infiltration capacity, when large storms occur or farmers irrigate the land excess water will just runoff of the land. If farmers leave wetland areas intact, the excess water will accumulate in them and slowly recharge the surrounding landscape during dry periods. Not only is this process better preformed by natural wetlands than by dugouts, waterbirds prefer natural wetlands. Furthermore, waterbirds are the main predator of aquatic insect larvae such as chironomidae, which have been known to be pest species in some crops (Green and Elmberg 2014). Although avoiding wetlands during agricultural activities may be more labor intensive, the long-term benefits will outweigh the initial inputs.

#### **4.3. Future work**

Using bioindicators to assess and monitor wetlands has many benefits over more traditional methods that only rely on abiotic variables (Cairns et al. 1993, U.S EPA. 2002, Burger 2006, Siddig et al. 2016). Indices of Biotic Integrity (IBI's) are especially appealing as monitoring and assessment tools because they allow you to select metrics to avoid sensitivity to

inter-annual variation (Karr 1999). In contrast, other methods of developing monitoring tools such as the multivariate approach, requires the consideration of all species, making it impossible to purposefully exclude metrics that are more driven by variation in hydroperiod than by human activity. My findings can be used in future work to inform the development of IBI's for the NP&PR and to inform study methodology as I have found that data collected over a 2-year period is not reflective of long-term conditions. Thus, moving forward, research should attempt to encompass the monitoring of biotic assemblages and environmental variables on a time scale greater than 2-years.

These chapters can be utilized to inform policy, conservation, and management of non-permanent marshes, particularly in the NP&PR of Alberta. This is the first study to assess the sensitivity of waterbirds within non-permanent marshes in NP&PR of Alberta. The findings help fill knowledge gaps that have limited policy development around non-permanent marshes and contribute to the basis of waterbird knowledge in the NP&PR.

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## 6. Appendices

### Appendix 1: Climate normals compared with seasonal and yearly averages.

Climate normals compared with seasonal and yearly averages in weather stations representative of the Parkland and Grassland natural regions. Temperature (°C), Rain (mm), Snow (cm), Precipitation (mm). Weather station representing Parkland is located in Stettler, whereas and Verger/Gem weather station represents Grassland.

Date	Natural Region			
	Parkland		Grassland	
	Temp	Precip	Temp	Precip
Normal (1981-2010)	3.3	477.6	4.5	303.9
Annual 2014	2.8	353.4*	3.4	329.3*
Annual 2015		377.2*		285.9*
May-September Normal (1981-2010)	14.3	292.2	15.6	187.0
May-September 2014	13.7	258.4	15.5	254.1
May-September 2015	14.7	226.0	15.7	187.5

\*Accumulated precipitation to September 30<sup>th</sup>

**Appendix 2: Snow depth data 2013-2015.** Data from Gadsby and Clive (Parkland natural region) long-term monitoring stations, collected in 2013, 2014 and 2015 in March (Mar) and April (Apr). Historical statistics are based on 30 years of data. Retrieved from Alberta Environment and Sustainable Resource Development (Government of Alberta 2015). Snow survey data is limited, however qualitative field observations noted snow in the Grassland in May, 2014 compared to no snow in May, 2015. These observations and data indicate that 2015 received less winter precipitation or was warmer throughout the spring months and resulted in a more gradual melt of snow. The gradual melt of snow instead of a spring ‘freshet’ where large accumulations of snow pack melt could result in a decrease of wetland water depth and length of hydroperiod. If snow melts gradually, greater infiltration to upland areas may occur and less runoff will be directed to wetland depressions. Note that the Clive station exceeded historical maximum snow depth in both 2013 and 2014.

Station	2015 Snow		2014 Snow		2013 Snow		Historical		Historical		Historical	
	Depth (cm)		Depth (cm)		Depth (cm)		Min.		Max.		Avg.	
	Mar	Apr	Mar	Apr	Mar	Apr	Mar	Apr	Mar	Apr	Mar	Apr
Gadsby	8	0	29	22	28	27	0	0	36	29	12	4
Clive	34	0	60	56	38	43	8	0	56	42	32	19

Government of Alberta. 2015. Plains Snow Course Data and Historical Rankings. Alberta Environment and Sustainable Resource Development

**Appendix 3: Beaufort Wind Scale.** Used for determining appropriate conditions for waterbird surveys. Wind conditions scoring above three are too strong for conducting auditory point counts.

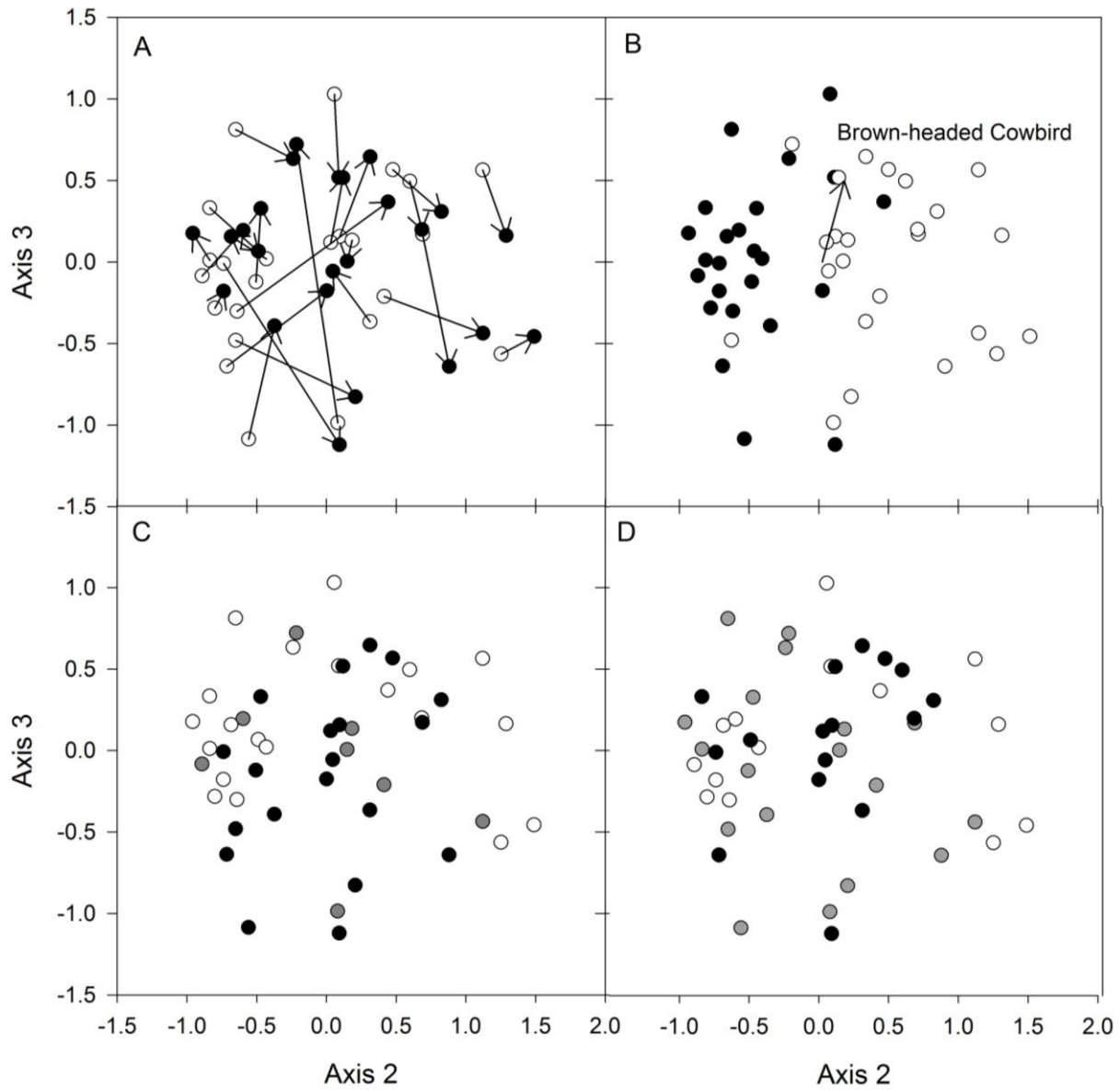
Number	Wind speed (km/h)	Indicators
0	0 to 2	Calm, smoke rises vertically
1	3 to 5	Light air movement, smoke drift
2	6 to 11	Slight breeze, wind felt on face
3	12 to 19	Gentle breeze, leaves and small twigs in constant motion
4*	20 to 30	Moderate breeze, small branches are moving, raising dust and loose paper
5*	31 to 39	Fresh breeze, small trees in leaf beginning to sway. Crested wavelets form
6*	40 to 50	Strong breeze, large branches in motion

**Appendix 4: Classification tree results summary.** Based on pruned model with 10 terminal nodes. Total residual mean deviance:

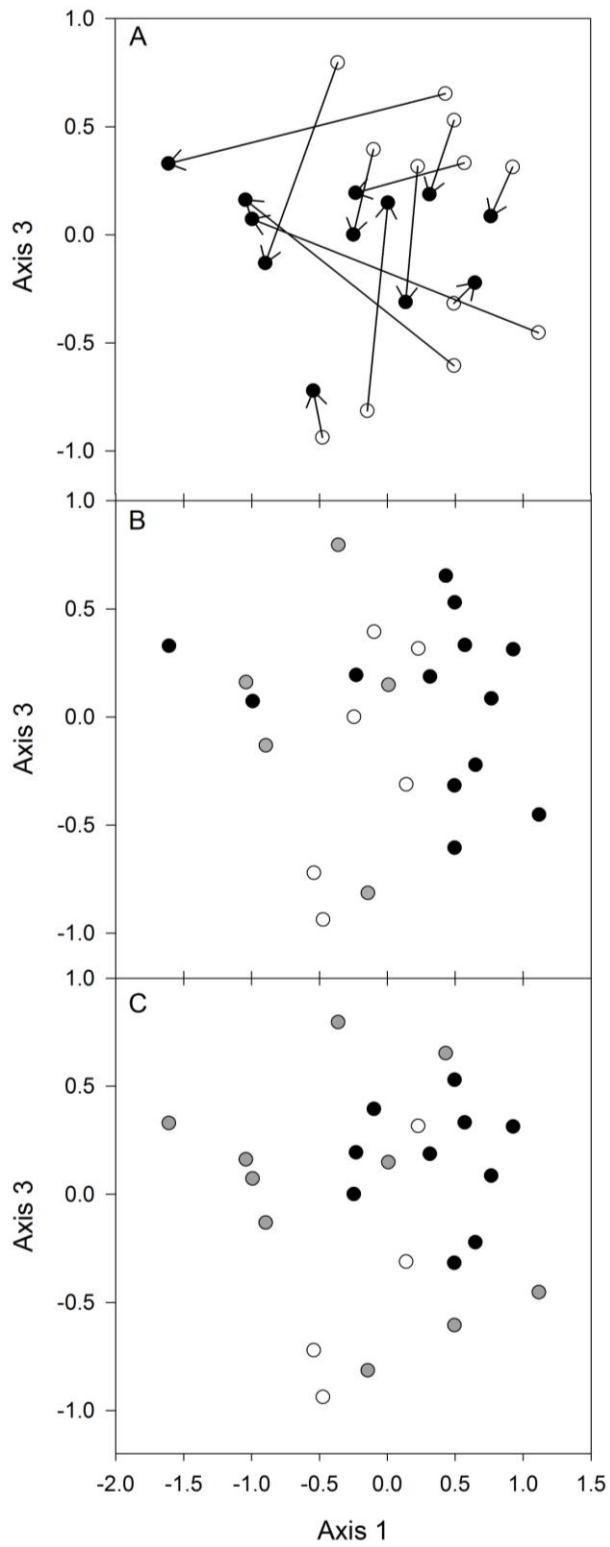
0.9531 = 36.22 / 38 where 36.22 is the residual deviance and 38 is N-#nodes. \*Indicates a terminal node

Node	Predictor Variable	Threshold Value	N	Deviance	Corresponding Assemblage
1	Root	- -	48	158.60	-
2	Forest&Shrubs500	< 4.59	28	62.18	-
4	Robust Emergent	< 11.34	23	41.49	-
8	Water&Wetlands500	< 0.54	7	13.38	-
16	Pasture500	< 2.20	5	5.00	-
17	Pasture500*	> 2.20	2	0.00	Deep open canopy
9	Water&Wetlands500	> 0.54	16	19.26	-
18	Max Depth (m)*	< 0.28	2	2.77	Shallow open canopy
19	Max Depth (m)*	> 0.28	14	7.21	Deep open canopy
5	Robust Emergent*	> 11.34	5	6.73	High disturbance emergent
3	Forest&Shrubs500	> 4.59	20	57.79	-
6	Robust Emergent	< 0.56	14	34.71	-
12	Pasture500*	< 7.68	5	5.00	Low disturbance woody
13	Pasture500	> 7.68	9	16.86	-
26	Exposed&Urban500*	< 2.56	5	5.00	Woody
27	Exposed&Urban500*	> 2.56	4	4.50	Low disturbance woody
7	Robust Emergent	> 0.56	6	7.64	-
14	Water&Wetlands500*	< 10.23	2	0.00	Woody
15	Water&Wetlands500*	> 10.23	4	0.00	High disturbance emergent

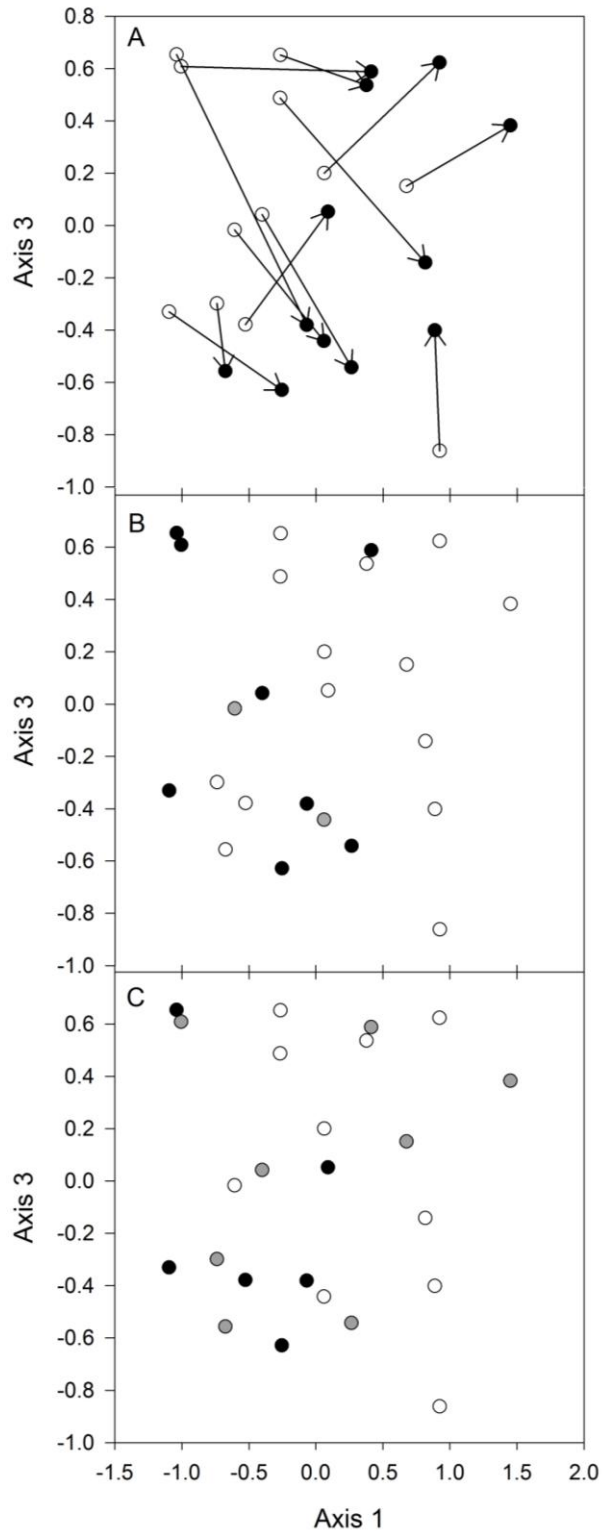
**Appendix 5: Ordination of all wetlands.** Joint plot of wetlands for all sites positioned in species space by non-metric multi-dimensional scaling ordination. (A) White circles represent 2014 data; black are 2015 data. Vectors represent the change from identical sites in 2014 to 2015. (B) Coded by region, Grassland sites are black and Parkland sites are white. The vector represents species correlation with axis 3. (C) Coded by disturbance, white <25% non-natural cover, grey 25-75% non-natural cover and black >75% non-natural cover. (D) Coded by marsh permanence class, white are class II wetlands, grey are class III and black are class IV wetlands. Disturbance and permanence class is not stratified on axis 3 in panel C and D and vectors in (A) have no obvious pattern.



**Appendix 6: Ordination of Parkland Axis 3.** Joint plot of wetlands for Parkland sites positioned in species space by non-metric multi-dimensional scaling ordination. (A) White circles represent 2014 data; black circles are 2015 data. Vectors represent the change from identical sites in 2014 to 2015. (B) Coded by disturbance, white <25% non-natural cover, grey 25-75% non-natural cover and black >75% non-natural cover. (C) Coded by permanence class, white circles are class II wetlands, grey are class III and black are class IV. Vectors in (A) have no clear pattern. Disturbance and permanence classes are not stratified on axis 3 in panel B or panel C. Additionally, no correlations with species vectors exist for axis 3.



**Appendix 7: Ordination of Grassland Axis 3.** Joint plot of wetlands for Grassland sites positioned in species space by non-metric multi-dimensional scaling ordination. (A) White circles represent 2014 data; black circles are 2015 data. Vectors represent the change from identical sites in 2014 to 2015. (B) Coded by disturbance, white <25% non-natural cover, grey 25-75% non-natural cover and black >75% non-natural cover. (C) Coded by permanence class, white circles are class II wetlands, grey are class III and black are class IV. Vectors in (A) have no obvious pattern and disturbance is not stratified on axis 3 in (B) and no correlations with species vectors exist for axis 3. Marsh permanence class is also not clearly separated by axis 3.



**Appendix 8: Functional guilds of waterbird species included in analysis.** Dietary: O = omnivore, C = carnivore, G = granivore, I = insectivore; Foraging: A = aerial, G = ground, C = canopy, DI = diving, DA = dabbling; Nesting: G = ground, C = canopy, F = floating; Migratory: M = migrant, R = resident.

<b>Common Name</b>	<b>Scientific Name</b>	<b>Dietary</b>	<b>Foraging</b>	<b>Nesting</b>	<b>Migratory</b>
Alder Flycatcher	<i>Empidonax alnorum</i>	I	A	G	M
American Avocet	<i>Recurvirostra americana</i>	I	G	F	M
American Coot	<i>Fulica americana</i>	I/G	DI	F	M
American Crow	<i>Corvus brachyrhynchos</i>	O	G	C	M
American Robin	<i>Turdus migratorius</i>	I/G	G	C	M
Baird's Sparrow	<i>Ammodramus bairdii</i>	I/G	G	G	M
Baltimore Oriole	<i>Icterus galbula</i>	I	C	C	M
Barn Swallow	<i>Hirundo rustica</i>	I	A	C	M
Black Tern	<i>Chlidonias niger</i>	I/C	A	F	M
Black-billed Magpie	<i>Pica hudsonia</i>	O	G	C	R
Black-capped Chickadee	<i>Poecile atricapillus</i>	I	C	C	R
Blue-winged Teal	<i>Anas discors</i>	I/G	DA	G	M
Brewer's Blackbird	<i>Euphagus cyanocephalus</i>	I/G	G	G	M
Brown Thrasher	<i>Toxostoma rufum</i>	O	G	G	M
Brown-headed Cowbird	<i>Molothrus ater</i>	I/G	G	C	M
Canada Goose	<i>Branta canadensis</i>	G	G	G	M

Common Name	Scientific Name	Dietary	Foraging	Nesting	Migratory
Canvasback	<i>Aythya valisineria</i>	I/G	DI	F	M
Chipping Sparrow	<i>Spizella passerina</i>	I/G	G	G	M
Clay-colored Sparrow	<i>Spizella pallida</i>	I/G	C	G	M
Common Raven	<i>Corvus corax</i>	O	G	C	R
Common Yellowthroat	<i>Geothlypis trichas</i>	I	C	G	M
Downy Woodpecker	<i>Picoides pubescens</i>	I	C	C	R
Eastern Kingbird	<i>Tyrannus tyrannus</i>	I	A	C	M
European Starling	<i>Sturnus vulgaris</i>	I	G	C	R
Franklin's Gull	<i>Leucophaeus pipixcan</i>	O	G	F	M
Gadwall	<i>Anas strepera</i>	G	DA	G	M
Grasshopper Sparrow	<i>Ammodramus savannarum</i>	I	G	G	M
Green-winged Teal	<i>Anas crecca</i>	I/G	DA	G	M
Grey Catbird	<i>Dumetella carolinensis</i>	I/G	G	G	M
Hairy Woodpecker	<i>Picoides villosus</i>	I	C	C	R
Horned Grebe	<i>Podiceps auritus</i>	I	DI	F	M
Horned Lark	<i>Eremophila alpestris</i>	I/G	G	G	M
House Wren	<i>Troglodytes aedon</i>	I	C	C	M
Killdeer	<i>Charadrius vociferus</i>	I	G	G	M
Least Flycatcher	<i>Empidonax minimus</i>	I	A	C	M
Le Conte's Sparrow	<i>Ammodramus leconteii</i>	I	G	G	M

Common Name	Scientific Name	Dietary	Foraging	Nesting	Migratory
Lesser Scaup	<i>Aythya affinis</i>	I	DI	G	M
Lesser Yellowlegs	<i>Tringa flavipes</i>	I	G	G	M
Long-billed Curlew	<i>Numenius americanus</i>	I	G	G	M
Mallard	<i>Anas platyrhynchos</i>	O	DA	G	M
Marbled Godwit	<i>Limosa fedoa</i>	I	G	G	M
Nelson's Sharp Tail Sparrow	<i>Ammodramus nelsoni</i>	I	G	G	M
Northern Flicker	<i>Colaptes auratus</i>	I	G	C	M
Northern Pintail	<i>Anas acuta</i>	I/G	DA	G	M
Northern Shoveler	<i>Anas clypeata</i>	I	DA	G	M
Red-breasted Nuthatch	<i>Sitta canadensis</i>	I	C	C	R
Red-eyed Vireo	<i>Vireo olivaceus</i>	I	C	C	M
Redhead	<i>Aythya americana</i>	I/G	DI	F	M
Red-tailed Hawk	<i>Buteo jamaicensis</i>	C	A	C	M
Red-winged Blackbird	<i>Agelaius phoeniceus</i>	I	G	G	M
Ring-billed Gull	<i>Larus delawarensis</i>	O	G	G	M
Ruby-crowned Kinglet	<i>Regulus calendula</i>	I	C	C	M
Ruddy Duck	<i>Oxyura jamaicensis</i>	I	DI	G	M
Ruffed Grouse	<i>Bonasa umbellus</i>	O	C	G	R
Savannah Sparrow	<i>Passerculus sandwichensis</i>	I	G	G	M
Song Sparrow	<i>Melospiza melodia</i>	I	G	G	M

<b>Common Name</b>	<b>Scientific Name</b>	<b>Dietary</b>	<b>Foraging</b>	<b>Nesting</b>	<b>Migratory</b>
Sora	<i>Porzana carolina</i>	I/G	G	F	M
Sprague's Pipit	<i>Anthus spragueii</i>	I	G	G	M
Swamp Sparrow	<i>Melospiza georgiana</i>	I	G	G	M
Tree Swallow	<i>Tachycineta bicolor</i>	I	A	C	M
Upland Sandpiper	<i>Bartramia longicauda</i>	I	G	G	M
Vesper Sparrow	<i>Pooecetes gramineus</i>	I	G	G	M
Western Meadowlark	<i>Sturnella neglecta</i>	I	G	G	M
White-throated Sparrow	<i>Zonotrichia albicollis</i>	I	G	G	M
Willet	<i>Tringa semipalmata</i>	I	G	G	M
Wilson's Phalarope	<i>Phalaropus tricolor</i>	I	G	F	M
Wilson's Snipe	<i>Gallinago delicata</i>	I	G	G	M
Yellow Warbler	<i>Setophaga petechia</i>	I	C	G	M
Yellow-headed Blackbird	<i>Xanthocephalus xanthocephalus</i>	I	G	G	M