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AVIAN SPECIES-AREA RELATIONSHIPS AND ENVIRONMENTAL COVARIATES IN NATURAL AND CONSTRUCTED WETLANDS OF NORTHEASTERN ALBERTA

by

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Avian species-area relationships and environmental covariates in natural and constructed wetlands of northeastern Alberta

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DECLARATION OF ORIGINALITY

I hereby certify that I am the sole author of this thesis and that no part of this thesis has been published or submitted for publication. I hereby declare that this thesis incorporates material that is result of joint research, as follows: This thesis incorporates the outcome of a joint research undertaken in collaboration with Marie-Claude Roy under the supervision of Dr. Lee Foote. The collaboration is covered in Chapter 2 of the thesis. Marie-Claude Roy designed the survey methods and collected the data on plant species richness that are detailed in chapter 2. The analysis and writing of chapter 2 of this thesis was completed by myself only.

I certify that, to the best of my knowledge, my thesis does not infringe upon anyone's copyright nor violate any proprietary rights and that any ideas, techniques, quotations, or any other material from the work of other people included in my thesis, published or otherwise, are fully acknowledged in accordance with the standard referencing practices. Furthermore, to the extent that I have included copyrighted material that surpasses the bounds of fair dealing within the meaning of the Canada Copyright Act, I certify that I have obtained a written permission from the copyright owner(s) to include such material(s) in my thesis and have included copies of such copyright clearances to my appendix.

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ABSTRACT

I examined the patterns of species distribution and richness as they relate to area in boreal wetlands of northeastern Alberta. I conducted point counts of bird species in natural and constructed wetlands of various sizes. Plant species richness, habitat attributes, and habitat heterogeneity were also estimated to determine whether these factors influenced the strength of the avian species-area relationship The species-area relationship was statistically significant in natural but not in constructed wetlands. Plant richness varied independently of area for both wetland classes. Area and anthropogenic disturbance were significant predictors of avian species richness in natural wetlands, but richness was uncorrelated with all variables in constructed wetlands except for habitat heterogeneity. Although mean avian species richness was similar between natural and constructed wetlands overall, community composition differed markedly and was most likely related to natural wetlands' greater age, larger size and distance from busy roads relative to constructed wetlands.

DEDICATION

For my parents and family. Thank you.

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LIST OF ABBREVIATIONS

LogAge: Log(age of a wetland).

LogArea: Log(total area of a wetland) (open water + emergent vegetation zones).

LogAreaEmerg: Log(area of the emergent vegetation zone of a wetland).

LogAreaOW: The log transformed area of open water zone of a wetland.

LogAvianSpp: The log transformed avian species richness of a wetland.

LogNrDisturb: The log transformed value of the distance to the nearest disturbance.

LogNrForest: The log transformed values of the distance to the nearest forest.

LogNrRoad: The log transformed values of the distance to the nearest road.

LogNrWater: The log transformed values of the distance to the nearest body of water.

LogNrWetl: The log transformed values of the distance to the nearest wetland.

LogPerEmerg: The log transformed values of the perimeter of the emergent vegetation in a wetland.

LogPlantSpp: The log transformed plant species richness of a wetland.

PctEmergentVeg: Relative cover (percent of total area) of the wetland habitat that was dominated by emergent vegetation.

PctMudSandRock: Relative cover (percent of total area) of the wetland habitat that was dominated by mud, sand or rock.

PctOpenWater: Relative cover (percent cover) of the wetland habitat that was dominated by open water.

PctShrub: Relative cover (percent cover) of the wetland habitat that was dominated by shrubs.

PctTreed: Relative cover (percent cover) of the wetland habitat that was dominated by trees.

CHAPTER I

GENERAL INTRODUCTION

The Species-Area Relationship

Generally, as the size of an island-like habitat type increases so does the number of species present in that habitat. This phenomenon is known as the species-area relationship. Originally identified in plants (Jaccard 1912, Arrhenius 1921), the species-area relationship has been demonstrated in many taxa (Connor and McCoy 1979, Gilbert 1980, Schoener and Schoener 1981, McGuinness, 1984a, b, Dunn and Loehle 1988). In fact, the species-area relationship is considered to be one of the most dependable phenomena in ecology (Schoener 1976). For example, Watling and Donnelly (2006) reviewed 118 published species-area relationship studies that included bats, herptiles, birds, invertebrates and non-flying mammals. Of these, 91% of the species-area relationships were positive, only 1% were negative, and in 8% species richness was independent of area.

The species-area relationship is expressed by the power curve equation (Arrhenius 1921)

$$S=cA^{z} \tag{1}$$

where S is the number of species, A is the area and c and z are coefficients. This expression is commonly log transformed to give a linear relationship of the form (Preston 1960)

$$\log S= z \log A + \log c \tag{2}$$

where z is the slope of the relationship and c is the y-intercept.

The species-area relationship has had practical application in conservation planning (Diamond 1976). It has been suggested that species-area curves may be used to set conservation guidelines in order to protect biodiversity by setting targets for the minimum size of preserves (Desmet and Cowling 2004), estimating the likelihood of extinction resulting from habitat fragmentation (Thomas et al. 2004), and being applied to Indices of Biotic Integrity to indicate the quality of a habitat (DeLuca et al. 2004, Niemi and McDonald 2004). Similarly, species-area relationships may be used to identify species that are area-sensitive (are more likely to occur with increasing habitat size) (Brown and Dinsmore 1986, Naugle et al. 1999, Riffell et al. 2001). For example, Riffell et al. (2001) found that American Bitterns, Swamp Sparrows, mallards, Virginia Rails, Soras, Eastern Kingbirds, Sedge Wrens, Red-winged Blackbirds, and American Goldfinches were all positively associated with area in the Great Lakes coastal wet meadows.

There are a number of explanations for what underlies the species-area relationship. MacArthur and Wilson (1967) explained the pattern as a model of dynamic equilibrium between immigration and extinction. Another explanation may be that the number of different habitat types tends to increase with area, and different species are adapted to different habitats. Thus, habitat heterogeneity may better explain the species-area relationship than colonization dynamics (Williams 1964). Finally, the species-area relationship has been argued to be merely an artefact of random sampling (Connor & McCoy, 1979). I describe these theories in more depth below.

1) Theory of Island Biogeography (area *per se*)

The theory of island biogeography (MacArthur and Wilson 1967, sometimes considered the area *per se* hypothesis due to it considering area as the only explanatory factor) attempts to determine and explain the species-area relationship in insular habitats in terms of island area and island isolation. According to the MacArthur and Wilson equilibrium model (1967), the species diversity of an island is determined by the balance between immigration (the establishment of a new species) and extinction (extirpation of an established species). The rate of immigration of species to an island is greater on larger islands because they provide large targets for immigrants and can sustain larger populations, which reduces the risk of extinction due to stochastic processes. Immigration rate declines as the number of species already present becomes larger. Similarly, the rate of immigration is proportionately lower on smaller islands, which provide smaller targets for immigrants and the likelihood of extinction due to stochastic processes is relatively high because small islands sustain smaller populations. Isolation also plays a role; the more isolated an island is from the mainland and other islands, the less likely immigration to the island becomes, and the more likely extinction. Thus, isolation fosters low diversity. The number of species present on an island is approximately constant when equilibrium is reached and immigration and extinction rates have the same value. This is referred to as the turnover point and is characterized by constant overall species richness but a potentially dynamic species composition.

The equilibrium number of species is determined by two factors - island isolation and island area. Small islands in close proximity to one another exhibit relatively large turnover in species composition because they are subject to frequent immigration and extinction. The community composition is driven by stochastic events. Isolated and small islands are species-poor because they experience low rates of immigration due to their distance from the mainland coupled with high rates of local extinction due to limitations of population size caused by the islands' small area. When islands are large and close together, they tend to support communities similar to those on the mainland. Dispersal is common due to proximity, and extinction is low because of larger population size. Islands that are large and isolated, however, tend to be rich in endemic species. Because they receive little immigration and have less extinction, the communities tend to be subject to genetic drift (Losos and Schluter 2000). As a result of these interactions there is a relationship between the area and isolation of an island and the number of species that can it can support. The theory of island biogeography has been extrapolated from islands and successfully applied to many fragmented and island-like habitat types on the mainland (Moller and Rordam 1985, Dzwonko and Loster 1989, Ouborg 1993).

2) Habitat Diversity Hypothesis

Developed by Williams (1964), the habitat diversity hypothesis proposes that as the area of an island increases so does the number of different habitats, and this results in the increase in species richness with an increase in area. In support of this, habitat quality does tend to increase with area (Wilcove 1985, Gibbs and Faaborg 1990, Burke and Nol 1998), and increasing habitat heterogeneity allows colonization of species that require specific or multiple habitat types (Weller 1999, Lor and Malecki 2006, Guadagnin and Maltchik 2007). According to this theory, area is a proxy for habitat diversity, which is what actually determines species richness.

3) Passive Sampling

It is possible that the species-area relationship is the result of passive sampling of the species pool (Connor and McCoy 1979). Larger islands will have more individuals and thus are likely to have greater overall species. This theory does not include biological factors such as habitat characteristics or population dynamics but rather views the species-area relationship as being completely a phenomenon of sampling. Connor and McCoy (1979) have suggested that the passive sampling model should first be tested as the null hypothesis before invoking either area or habitat heterogeneity as explanations for species richness.

An Integrated Approach

It is difficult to assess or distinguish the relative importance of these three hypotheses in explaining the species-area relationship (Connor and McCoy 1979). Island area and isolation may influence habitat diversity by determining plant species diversity (Connor and McCoy 1979), and teasing apart the area and habitat effects is challenging because they are usually correlated (Wiens 1989, Rosenzweig 1995). All three of these hypotheses have received support in empirical studies; therefore a combination, rather than any single model, need to be simultaneously evaluated to determine mechanisms behind the species-area relationship (Johnsson et al. 2009) for any particular system. A large island that is low in habitat diversity is unlikely to be species rich, and a small habitat-diverse island will only be able to support a few individuals or species. Finally, sampling effort must be sufficient to detect a large enough number of individuals that a researcher can be confident that the species pool has been effectively surveyed. A powerful study requires one to consider potentially important covariates (e.g., habitat diversity) as well as the independent variable of greatest interest (area) to best describe species richness. Indeed, a few studies have found that considering area and habitat diversity together explains more variability than either one on its own. For example, Ricklefs and Lovette (1999) assessed birds, bats, reptiles and butterflies and found that island area and diversity had different relationships to species richness for the four taxonomic groups. Similarly, Panitsa et al. (2006) reported that plants on small islands did display species-area relationships but that other factors such as elevation and the presence of grazing species, also explained significant portions of the variance. Therefore, an integrated approach is most likely to explain the full picture of what determines species diversity.

Wetlands, Birds and the Species-Area Relationship

Wetlands are considered to be highly productive and diverse ecosystems (Alsfeld et al. 2010). Many terrestrial and aquatic species are supported by the ecotone between upland and fully aquatic ecosystems that wetlands represent. Wetlands support biota exclusive to wetlands (Gibbs 1995) as well as many rare and endangered species (Whitelaw et al. 1989). Despite their biological significance, wetlands are a threatened habitat (Williams 1993), subject to worldwide degradation and loss due to human activities (Wilen 1989). Recently, increasing public awareness of wetlands' biological significance has resulted in concern over the consequences of wetland habitat loss (Dugan 1990).

Wetlands are analogous to islands in that they are a naturally patchy habitat type and therefore one expects them to display relationships consistent with the principles of island biogeography (Guadagnin and Maltchik 2007). Until recently, wetland habitats have received relatively little study from a species-area relationship perspective (Benassi et al. 2007) despite the facts that wetlands provide important nesting habitat for birds as well as stopover sites during migration (Smith and Chow-Fraser 2010) and that there are avian species that nest only in wetlands that have been experiencing large scale declines in numbers (Sauer et al. 2008).

Species-area relationships for birds have been documented across the globe (Preston 1960) and within specific habitats (Smith and Chow-Fraser 2010). In fact, birds are often considered a model organism for the study of species-area relationships (Benassi et al. 2007). The majority of recent publications have reported that wetland avifauna do display a positive species-area relationship (Burger et al. 1982, Tyser 1983, Brown and Dinsmore 1986, Gibbs et al. 1991, Craig and Beal 1992, Celada and Bogliani 1993, Findlay and Houlahan 1997, Mamo and Bolen 1999, Báldi and Kisbenedek 2000, Colwell and Taft 2000, Riffell et al. 2001, Paracuellos and Telleria 2004, Shriver et al. 2004, Paracuellos 2006, Benassi et al. 2007, Guadagnin and Maltchik 2007, Craig 2008, Guadagnin et al. 2009, Gonzalez-Garjardo et al. 2009, Tsai et al. 2012) with the exception of one study that failed to detect a species-area relationship (Fairbairn and Dinsmore 2001).

Clearly, the area of a wetland is an important factor in conservation and restoration of wetland avian diversity. Brown and Dinsmore (1986) surveyed marshes in Iowa and found that 68 percent of marsh bird species are either absent or found in reduced numbers at small marshes (those less than 5 ha in area). Further support of this comes from Smith and Chow-Fraser (2010) who found a significant positive relationship between marsh-obligate species richness and the area of Great Lakes coastal marshes, and that the probability of detecting a marsh nesting species was greater in a marsh 5.52 ha in area or larger. Craig (1990, Craig and Beal 1992, Craig 2008) has documented that rare species of bird are only detected at the largest marsh habitats. Additionally, when area is small, as a result of wetland habitat fragmentation, habitat specialists are reduced in population numbers while generalist population sizes increase (Bellamy et al. 1996), which results in the specialist species becoming more likely to go extinct. Thus, it is crucial that we understand how wetland habitat area alters species richness in order to conserve and restore avian biodiversity.

Within wetlands, both the theory of island biogeography and the habitat heterogeneity hypothesis have received support for explaining species richness. Wetland area and isolation have been associated with avian species richness (e.g.: Brown and Dinsmore 1986), in accordance with island biogeography theory, the habitat diversity hypothesis has also received support for wetlands birds as the vegetation diversity and spatial complexity are associated with wetland bird diversity (e.g., Gibbs et al. 1991). Human impacts are also important predictors of avian species richness (Cottam and Bourne 1952, Clarke et al. 1984, Findlay and Houlahan 1997). Furthermore, activities outside of the immediate wetland area may alter wetland functions due to wetlands' hydrological connections to nearby watersheds (Gleason and Euliss 1998; Houlahan and Findlay 2003; Smith et al. 2008). Given that wetland avian species richness is explained by several habitat variables, conservation and restoration of wetlands must be considered from all angles. Failure to do so would likely result in wetlands incapable of sustaining a diverse avian community.

Species-Area Relationships and the Trophic Cascade

As previously mentioned, the theory of island biogeography suggests that species richness of an island is determined by island area and isolation, with immigration and extinction acting as the mechanisms (MacArthur and Wilson 1967). Immigration is greater on large, islands that are near a mainland while extinction occurs on small and distant islands due to density-related factors. The patterns can be modified by a group's trophic position (either top-down or bottom-up control of populations; Holt 2010) as well as by stochastic events.

A separate theory, the productive space hypothesis (Schoener 1989), proposes that plant productivity determines food chain length (Holt 1996) because primary producers facilitate colonization of species that occupy trophic levels high in the food web; and a species can only colonize a habitat if its lower trophic level resources are already present (Holt et al. 1999). Combined, these two ideas suggest that the diversity of the primary producers of an ecosystem may limit the potential richness of species at higher trophic levels such that the number of species at a given area will vary depending on the number of species at the lower trophic levels.

To address trophic issues in island biogeography, Holt et al. (1999) proposed the stacked specialist model in which low trophic level prey must be present before species at higher trophic levels colonize. Further, because species at higher trophic rank tends to be less abundant than their prey for energetic reasons, high trophic level species are more likely to go extinct on smaller islands (Schoener 1989). The lower abundance of consumers and their dependence on prey populations should result in consumers displaying stronger species-area relationships than their food source (Holt 2010). Holt et al. (1999) reviewed the literature and were able to detect this trend in seven out of the eight studies that looked at trophic effects in species-area relationships. Subsequently, Holt et al. (1999) provided further explanation of factors that may alter a trophic island biogeography:

1) It is possible that higher trophic level species may persist in their habitat without their lower trophic level food source if a consumer is mobile and able to obtain prey from other habitats that are sufficiently close, and therefore weaken trophic effects on species-area relationship. Holt et al. (1999)

2) In order for the productive space hypothesis to pertain, predators must display weak top-down control on prey species. If larger islands have more predators, they may exert top-down control of prey populations and even cause potential extinction of the prey species. In such a situation, prey species richness would actually decline as island area increases or have a flat relationship (Holt 1996a, b). Holt et al. (1999) regarded this as a possibility on

large islands but that predators would rarely have such strong effects on their prey populations.

3) Generalists have the potential to weaken or strengthen trophic effects on the species-area relationship, depending on the class of generalist. Obligate generalists would strengthen the effect of trophic rank on the species-area relationship because they must consume several different species to get their nutritional needs and therefore depend on the presence of multiple lower trophic level species. Opportunistic generalists, on the other hand, likely weaken trophic effects on the species-area relationship because these consumers can feed on a suite of potential prey. Furthermore, generalists add interspecies competition to the relationship. Specialists require a particular food source but generalists forage on many different lower trophic level species and have overlapping diets; thus, they compete with other species that require that food source and this can have many complex consequences for trophic effects on species-area relationships. Further, prey subject to population pressure from several different predators.

4) Island habitats that have not reached equilibrium may or may not display trophic effects on species-area relationship, if species-area relationships are detected at all. In classic descriptions of succession (Clements 1916) plants colonize first, followed by herbivores and then predators and eventually parasites arrive. In such a situation we would expect higher trophic level species to display a stronger relationship to island area. However, when habitats are colonized in a way that is not classic succession, trophic rank effects will be less likely to influence the species-area relationship.

Holt et al. (1999) pointed out that while studies of species-area relationships are numerous, very few researchers simultaneously examine a range of taxa that differ in trophic rank within an array of island or habitat archipelagos (Spencer, 1995). I found only one multitaxon study of wetlands, and these authors did not specifically review trophic status in their results; Findlay and Houlahan (1997) did not fully confirm trophic species-area relationships as mammals displayed the weakest relationship (lowest z-value) with wetland area. However, after mammals, plant species exhibited the weakest relationship followed by birds and then herptiles. Clearly, more investigation into trophic species-area relationships in wetlands is necessary.

Wetlands and Oil Sands

The oil sands area in the north-eastern region of Alberta covers over 140,000 km^2, representing one of the world's largest deposits of oil (Government of Alberta 2009). The oil is found in large deposits of a mixture of 'oxidized crude oil' (termed bitumen) and sand (del Rio et al. 2006) found beneath a shallow (<80 m deep) layer of sodic clay (Fine Tailings Fundamentals Consortium (FTFC) 1995).

To expose the subsurface oil sands the surface habitat and structures must be disturbed and removed, including the boreal forest community, up to 65% of which is wetland habitat (Raine et al. 2002). The soils are removed and stored to be later used in the process of land restoration (reclamation). This oil-sand mixture is then excavated and transported by truck to extraction plants on the company lease site.

The Alberta Environment Protection and Enhancement Act stipulates that the mining companies must re-establish both the pre-disturbance wildlife habitat types and restore the lease site to its original level of functionality (Oil Sands Wetlands Working Group 2000). As a result, the oil sand companies are investing in reclamation research to determine the most effective ways to return mined land to its pre-mining conditions. This process includes the construction of demonstration wetlands in various shapes and sizes as well as monitoring development of communities in opportunistic wetlands – water bodies that form spontaneously on the reclaimed landscape (Trites and Bayley 2009). Construction of suitable and self-sustaining habitat will be the primary factor in restoration of wildlife in the post-mining landscape (Johnson and Miyanishi 2008), and old growth forest birds are among the indicator organisms of interest (Axys Environmental Consulting Ltd. 2003).

Previous avian research on the natural and reclaimed wetlands of the oil sands region has focused primarily on toxicology of species using the wetlands (see Gurney et al. 2005, Gentes et al. 2006, 2007a, b, Harms et al. 2010). Only one study has examined richness or community level relationships in birds (Dagenais 2009). Dagenais (2009) surveyed wetlands containing oil sands process material-affected and reference wetlands (wetlands constructed or opportunistically forming within lease boundaries without the addition of oil sands process materials). She found that overall species richness had declined in the interval since the area had been previously surveyed (in 1983; Gully 1983). Dagenais (2009) also assessed habitat characteristics that correlated with greater wetland bird abundance and richness. She found water-nesting bird abundance was highest in older (≥8 y) and larger wetlands that contained oil sands process materials, and that abundance increased with increasing extent of submersed vegetation cover. Dagenais (2009) also found that abundance of tree-nesting species was best predicted by proximity of a wetland to forested areas, and shrub-nesting species abundance was highest at sites with dense shrub cover that were close to forest patches and wetlands. Species richness of birds that breed specifically in wetlands was related to ‘distance of the wetland to forest patch’ and ‘habitat type’. Greater overall species richness was found at wetlands located closer to forest patches. Dagenais’ research suggests that anthropogenic activity in the region resulted in declines of avian species richness and that habitat factors, such as distance to the nearest forest and wetland area, can influence avian richness and abundance. However, this research took place only on oil sands affected lands and did not compare the avian species richness and abundance to wetlands naturally occurring in the boreal forest area and thus was not an assessment of whether the constructed wetlands were similar to natural wetlands.

Research Objectives and Overview

Oil sand companies are constructing wetlands with the goal of reclaiming the post-mining landscape to the functional equivalent of a pre-mining state. In order to be certified as a ‘reclaimed’, wetlands, must be judged comparable to natural wetlands “on the basis” of several factors including the biota (in Raab and Bayley 2011).

Previous research on avian species in the Alberta oil sands constructed wetlands has demonstrated that birds are capable of colonizing and breeding on these wetlands and that wetland area and other habitat covariates are predictors of richness (Dagenais 2009). However, avian communities in these constructed wetlands have not been compared to natural boreal forest wetlands. Nor has there been an examination of the size of wetlands or the constituent habitat characteristics necessary to support avian communities typical to those of natural boreal forest wetlands. Further, research has tended to focus on one taxon group without considering the broader scale trophic relationships. Given the complex interactions among taxonomic groups in the food web, it may be beneficial to evaluate species-area relationships at the multitaxon scale when attempting to construct suitable and self-sustaining habitats.

In this study I performed point counts at natural and constructed wetlands in the Fort McMurray, AB, region. I related avian species richness to the area of the wetlands surveyed to determine if natural and constructed wetlands exhibit species-area relationships. Additionally the diversity of wetland bird communities was assessed in relation to the diversity of the wetland plant community to determine if trophic position alters the strength of the species-area relationship (Holt et al. 1999). I related avian species-area relationships to plant species-area relationships. I postulate that constructed wetlands would have lower plant and avian species richness than that of natural wetlands, and that avian species richness will be more strongly related to area than plant richness as expected in the staked specialist model (Holt et al. 1999). I also surveyed major habitat characteristics and related them to avian species richness to determine other important factors that may explain avian species richness, as has been demonstrated in other wetland studies. Finally, I compared avian species composition of the natural and constructed wetlands and explored factors that may explain community composition.

My research examines details of species area relationships in birds and wetland plant life. This is the first multitaxon comparative assessment of the relationship between area and biodiversity in constructed and natural wetlands of the oil sands landscape and the first study to compare factors that explain avian richness between natural and constructed wetlands. Research on the relationship between wetland size and other habitat variables and species richness as well as between plant and avian richness were expected to provide better understanding of the habitat requirements needed to build and conserve sustainable wetlands that are comparable to those found naturally.

This thesis is organized into 4 chapters. In chapter 2, I test for positive plant and avian species-area relationships in a suite of natural and constructed wetlands. I compare the slopes and intercepts of these relationships to determine if trophic effects exist within these wetlands. Chapter 3 examines environmental covariates of the species-area relationship; specifically factors of area, isolation and habitat diversity. The results of this chapter were expected to aid in clarifying the relative importance of these different factors to species richness as well as determine if constructed and natural wetlands differ in the variables that regulate avian species richness. The final summary chapter discusses the results of this study and combines them to provide recommendations for conservation and construction of wetlands in order to maximize avian species richness.

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CHAPTER II

RELATIONSHIPS BETWEEN AVIAN AND PLANT SPECIES RICHNESS AND THE AREA OF NATURALLY FORMED AND CONSTRUCTED WETLANDS

Introduction

The theory of island biogeography (MacArthur and Wilson 1963, 1967) attempts to explain the species-area relationship using island area and isolation as the driving forces controlling species richness. MacArthur and Wilson (1967) postulated that the species-area relationship occurs because large islands allow for greater likelihood of establishment and larger populations (which are less likely to go extinct) than can occur on small islands, whereas island isolation (distance from a regional species pool) reduces the probability of immigration of individuals and therefore is negatively related to richness (MacArthur and Wilson 1967). However, other factors, such as interspecific interactions (Lomolino 2000) must also play a role in the species richness of an island, because a species cannot colonize an island if the food resources necessary for its survival are not already present (Holt et al. 1999), and a consumer species cannot persist after losing its last prey species (Gravel et al. 2011). The theory of island biogeography fails to account for these biotic factors and assumes that immigration and extinction rates are determined by the physical characteristics of the island only (Lomolino 2000).

In the stacked specialist model, Holt et al. (1999) proposed that species that occupy a trophic position high in a food web can only colonize an island if their lower-trophic-level prey are present. Additionally, since population size tends to decline with increasing trophic rank, species at the top of a food web are more likely to go extinct than their more abundant prey at the base. This also makes high trophic level species more subject to sampling artifacts since individuals are less abundant and are therefore less likely to be detected than prey species on smaller islands (Hoylet 2004). When applying these concepts to the species-area relationship, the dependence of consumers on producer abundance and richness should result in consumers having a stronger species-area relationship than their prey (Hoylet 2004, Holt 2010). There has been support for this postulate in empirical studies (Itamies 1983, Nilsson et al. 1988, Kruess and Tscharntke 1994, Schoener et al. 1995, Hoylet 2004, Gravel et al. 2011). However, a few studies have not detected this trend (Mikkelson 1993, Polis unpubl. (cited in Holt et al. 1999)). In addition to these basic trophic effects, trophic generalism may strengthen or weaken the effect of trophic position on the species-area relationship (Hoylet 2004); on very large islands, where predators are less likely to go extinct, prey may be more likely to be driven to extinction due to high numbers of predators (Hoylet 2004).

Relatively few studies have undertaken multitaxon analyses of species-area relationships (Holt et al. 1999). Those that have analyzed multiple taxa tend to focus on true islands or fragmented forests. For example, Steffan-Dewenter (2003) observed trophic effects on the species-area relationships of trap-nesting bees, wasps, and their natural enemies in fragmented forest, although they failed to demonstrate effects of trophic specialization and generalism. Relatively little research has focused on multitaxa comparisons in wetlands and the research focus of the existing studies has not been to assess differences in trophic level species-area relationships. For example, Findlay and Houlahan (1997) observed significant species-area relationships in mammals, plants, birds and herptiles. However, their data did not fully correspond to the expected trophic level patterns because mammal species richness (constituting a group of consumers) was most weakly related to wetland area. Following mammals, the species-area relationship strengthened to plants, birds and finally herptiles had the strongest species-area relationship. Herptiles and birds, when considered as a group, are both omnivores; thus, it would be difficult to predict which should have the strongest relationship with area. However, both taxa clearly exhibited steeper slopes with respect to area than the producer plants, confirming the trophic island biogeography prediction in this instance whereas the comparatively weaker relationship of the omnivore mammals would counter it.

Natural habitats in the Athabasca oil sands region near Fort McMurray, Alberta are experiencing large scale disturbance and decline due to development for open-pit oilsands mining. Ongoing collaborative efforts are working towards restoring the disturbed landscape to its previous condition (Oil Sands Wetland Working Group (OSWWG) 2000). Since the mid 1980's, this has included the construction of demonstration wetlands of various sizes that have been colonized naturally by plants and other biota. The natural colonization of constructed wetlands provides a novel setting in which to study trophic dynamics (e.g. Kovalenko et al. 2013) and species-area relationships. Within this area, Dagenais (2009) found that greater wetland size was related to higher water-nesting species abundance but did not report on the relationship of area to overall species richness. It has been suggested that species-area relationships may be used to set conservation guidelines (Desmet and Cowling 2004) and knowledge of the relationship of species richness to wetland area in this region could be valuable in the reclamation process.

In this study, I examined the species-area relationships of wetland plants (producers) and avian species (consumers) in naturally-forming and constructed wetlands. I then compared the species-area relationships of plants and birds to determine if

a) producers are more species rich than consumers; and

b) the higher-trophic-level species do exhibit a stronger species area relationship.

This study is the first multitaxon approach to assess trophic species-area relationships in wetlands and certainly within constructed wetlands. This research further contributes to the body of evidence of how trophic level alters the species-area relationship and will provide guidelines for the conservation and restoration of wetland habitat in terms of the physical characteristic of wetland size.

Methods

Study Sites

Surveys were performed near Fort McMurray, Alberta on land leased by Suncor Energy Inc. and Syncrude Canada Ltd. as well as at offsite locations (Fig. 2.1). Surveys took place 19 June - 5 July 2011 and 16 May - 8 June 2012. In 2011, 15 marsh-like wetlands were surveyed. Wetlands were classified as either ‘constructed’ (n=8, between 2 and 40 years old) or ‘natural’ (n=7, between 29 and over 50 years old). In 2012, surveys were performed at 31 marsh-like wetlands of various sizes, 17 constructed and 14 natural. Constructed wetlands ranging in age from 7 to 41 years, had been built (or formed opportunistically) on cleared, leased mining lands. Most natural wetlands were situated on crown land and ranged in age from 32 years to indeterminate age (appearing on maps or aerial photos 30- 50 years old). Natural wetlands situated on the oilsands lease lands must have existed prior to the leasing of land for mining; they are not opportunistic.

Smoke from extensive forest fires affected the survey area during much of the 2011 field season. Those conditions and a late start to the survey period in 2011, rendered the bird survey data unreliable. Consequently, I used this data for a pilot study excluded these data from detailed analyses. The species-area analyses were based only on data obtained from the 2012 survey.

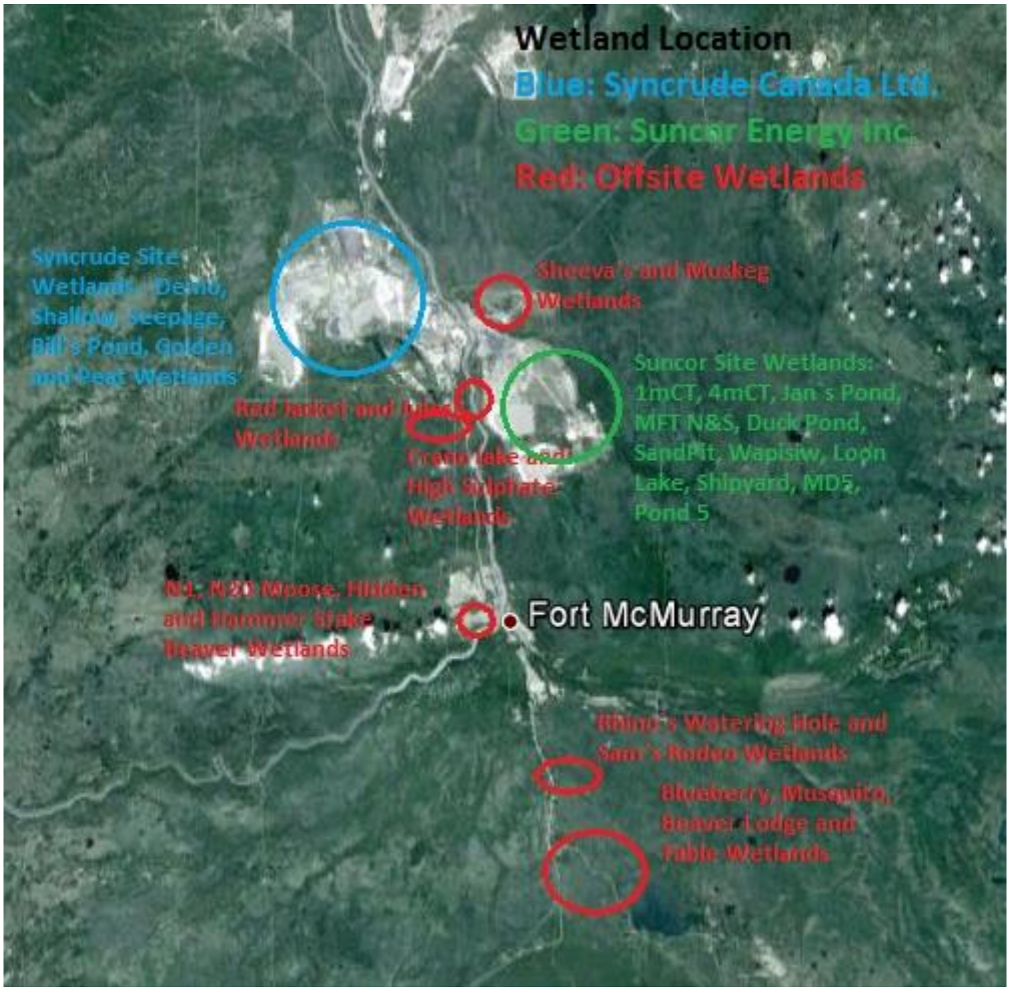

Figure 2.1. Satellite image (Google Earth Pro) of the study area. Syncrude Canada Ltd. Wetlands names are shown in blue text, Suncor Energy Inc. wetlands are coloured green and all wetlands that were found offsite are in red (Wetland geographic coordinates, class and alternative names are provided in Appendix I). The image is taken from Google Earth Pro.

Wetland Area and Distance Measures

I used Google Earth Pro (Google Inc. 2012) software to obtain aerial images of the wetlands from which I measured perimeter (m) and area (ha) of both the emergent vegetation and open water areas of each wetland. The open water zone is the portion of the wetland that is composed of only the exposed (visible) water area. The emergent vegetation zone was the portion of the wetland that contained vegetation that is raised out of the water. The total wetland area was obtained by summing the open water and emergent vegetation zone areas. Colour differences in the images were used to discriminate between the emergent and open water zones. The aerial images used were of the highest quality available and were taken in August and September between the years 2008-2010.

Avian Surveys

I used the 10-minute point count method (Bibby 2000) to survey avian communities, recording all birds seen or heard during the survey period, and noting the number of individuals of a species when possible. Point counts were performed during the dawn chorus between sunrise (approximately 0400 h) and 1000 h MDT. Point counts were only performed in fair weather conditions of no rain and low winds (<15 km/h). I performed point counts at three locations in each wetland. Where possible, each survey station was at least 200 m away from its nearest neighbour. When a wetland was not large enough to situate survey points 200 m apart I attempted to maximize the distance between stations.

Wetlands were often far apart and as a result it was difficult to sample them at random. Instead, wetlands that were in a similar area were grouped together. These ‘area groupings’ were then sampled in a random order until all wetlands had been sampled.

Plant Surveys

Plant species richness was tabulated by Marie-Claude Roy, (Ph.D. candidate, Department of Renewable Resources, University of Alberta) at 28 of the study wetlands (12 natural and 16 constructed) during the peak crop period near the end of August in the years 2010 and 2011. Surveys transected the submergent, emergent, and wet meadow zones along each of 3 lines radiating from the central point of each wetland. The open water zone is 2 m beyond (heading towards the center of the wetland) the established emergent zone. The emergent zone extended 2 m toward the wetland center and had a water depth greater than zero. Wet meadow zone must have shown clear signs of past or present submergence and have had a water depth equal to zero (i.e., damp or dry soil). Finally, the soil of the upland zone was damp or dry and had to have no evidence of current or past water saturation. The transect (point count) method was used within each zone. A measuring tape was stretched across the zone and observations were taken at 1-m intervals of each plant species touching or crossing the measuring tape. A total of 12 observations per wetland were performed, one in each of the four zones of the three replicate transects.

Statistical Analyses

Statistical analyses were conducted using STATISTICA 7 software (Statsoft, Inc., Tulsa, OK). I determined the mean and range of number of bird and plant species detected overall as well as the mean and range of total wetland area (emergent vegetation + open water). Independent-sample t-tests were performed to determine whether there was a difference in the mean number of avian species detected at constructed vs. natural wetlands as well as plant species at constructed vs. natural wetlands.

Simple regression analysis of the log-transformed data for species richness vs. log-transformed wetland total area was used to estimate species-area relationships for natural and constructed wetlands for both plants and birds. ANCOVA was used to determine if the slopes of the species-area relationships of plants and of birds differed between natural and constructed wetlands.

Results

Plant richness was estimated for 28 wetlands, 16 of which were classified as constructed and 12 of which were designated natural (Roy 2014). Wetland total area (emergent + open water) ranged from 0.15 to 151 ha. The arithmetic mean (±SD) wetland total area was 10.05±28.84 ha. A total of 144 plant species was recorded (excluding shrubs and trees) across all wetland zones. The number of plant species detected at each wetland ranged from 8 to 38 with an arithmetic mean±SD of 23.83±7.95 species averaged across all wetlands. Detailed data are provided by Roy (2014).

I surveyed 31 wetlands (17 constructed and 14 natural) for avian species richness, 28 of which had also been surveyed for plant richness (Appendix I). Wetland total size (emergent + open water) ranged from 0.15 ha to 151ha and the mean±SD wetland total area was 9.26±27.49 ha. Seventy-one avian species were observed across all wetlands. The mean±SD number of avian species detected at across the 31 wetlands was 14.06±3.80 (range 8-22). For comparison purposes, in the 2011 data excluded from analysis in this study, I surveyed 16 wetlands (7 constructed and 8 natural) for avian species richness. The mean number of species detected was 10.19±3.35 (mean±SD, range 4-16).

Significantly fewer plant species were found in constructed wetlands (mean ±SE 18.69±5.55 (n=16)) than in natural wetlands (30.67±4.91 (n=12)) (Independent samples t-test, t=5.94, $p<0.001$). In contrast, there was no significant difference in avian species richness between wetland classes (independent samples t-test, t=0.37, $p>0.05$). Although the difference was not significant, constructed wetlands had slightly more species on average (14.29±3.48 (n=17) than natural wetlands (13.79±4.28 (n=14)).

Regression analysis of log transformed data (Table 2.1, natural wetlands: Fig. 2.2; constructed wetlands: Fig. 2.3) indicated that plant species richness was independent of the total area of both natural (p=0.27) and constructed wetlands (p=73). A ($R^2 = 0.34$) statistically significant positive relationship was observed between avian species richness and the total area of natural wetlands (Table 2.2, Fig. 2.2; p=0.028). The relationship between avian species richness and constructed wetland area was also positive but was not statistically significantly greater than zero (Table 2.2, Fig 2.3; $R^2 = 0.08$, p=0.27).

ANCOVA was performed to determine if the species-area relationships for birds and plants were homogeneous within each class of wetlands. All natural wetlands supported more plant species than bird species (Table 2.3, Fig. 2.2). The slopes of the species-area relationships for plants and for birds in natural wetlands were highly significantly different (Table 2.4, $F_{1,23} = 68.25$, p<0.001) with birds having a stronger relationship to area than the plants. Differences were less marked in constructed wetlands. Plant richness was significantly greater than bird richness for constructed wetlands overall (Table 2.3, Fig 2.3, p=0.02). Neither species-area relationship was significantly greater than zero in the constructed wetlands, and the two slopes were not significantly different (Table 2.4, $F_{[1,30]}=6.08$, p=0.59), although the slope for plants was slightly negative whereas that for birds was slightly positive.

In summary, in natural wetlands, bird species richness was significantly positively related to wetland area whereas plant species richness was not and plant species richness was always greater than avian species richness in both wetland classes. Both bird and plant species richness was independent of the area of constructed wetlands. In natural wetlands avian species richness had a stronger relationship with area than plants but this was not found in constructed wetlands.

Table 2.1. Linear regression results of the log transformed data of species richness of the plant species-area relationship in natural (R^2=0.12, LogPlantSpp=1.4995-0.0292(LogArea)) and constructed wetlands (R^2=0.01, LogPlantSpp=1.2562 – 0.0268(LogArea)). Significant p-values (<0.05) are indicated by an asterisk (*).

Wetland Class		SS	Degr. Of Freedom	MS	F	p
Natural, n=12	LogArea	0.01	1	0.01	1.35	0.27
	Error	0.05	10	0.01		
Constructed, n=16	LogArea	0.00	1	0.00	0.13	0.73
	Error	0.29	14	0.02		

Table 2.2. Linear regression results of the avian species-area relationship in natural (R^2=0.34, p=0.028, LogAvianSpp=1.0655 + 0.1003(LogArea)) and constructed wetlands (R^2=0.08, p=0.27, LogAvianSpp= 1.1344 + 0.0614(LogArea)). Significant p-values (<0.05) are indicated by an asterisk (*).

Wetland Class		SS	Degr. Of Freedom	MS	F	p
Natural, n=14	LogArea	0.09	1	0.09	6.22	0.028*
	Error	0.17	12	0.01		
Constructed, n=17	LogArea	0.015	1	0.01	1.30	0.27
	Error	0.17	15	0.01		

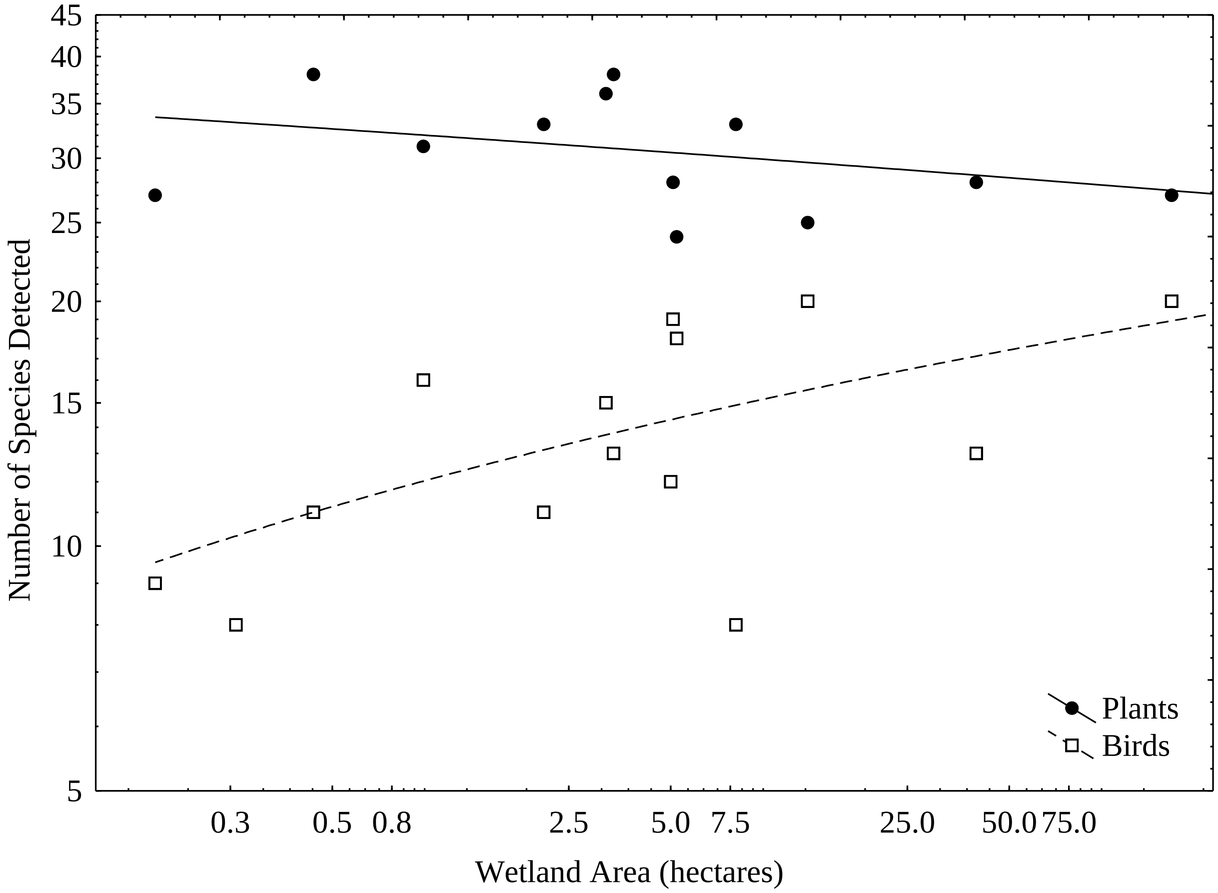

Figure. 2.2. Relationship between wetland area and plant (filled circles, LogPlantSpp=1.4995-0.0292LogArea, n=12, p=0.27) and avian (open squares, LogAvianSpp=1.0655 + 0.1003LogArea, n=14, p=0.028) species richness in natural wetlands.

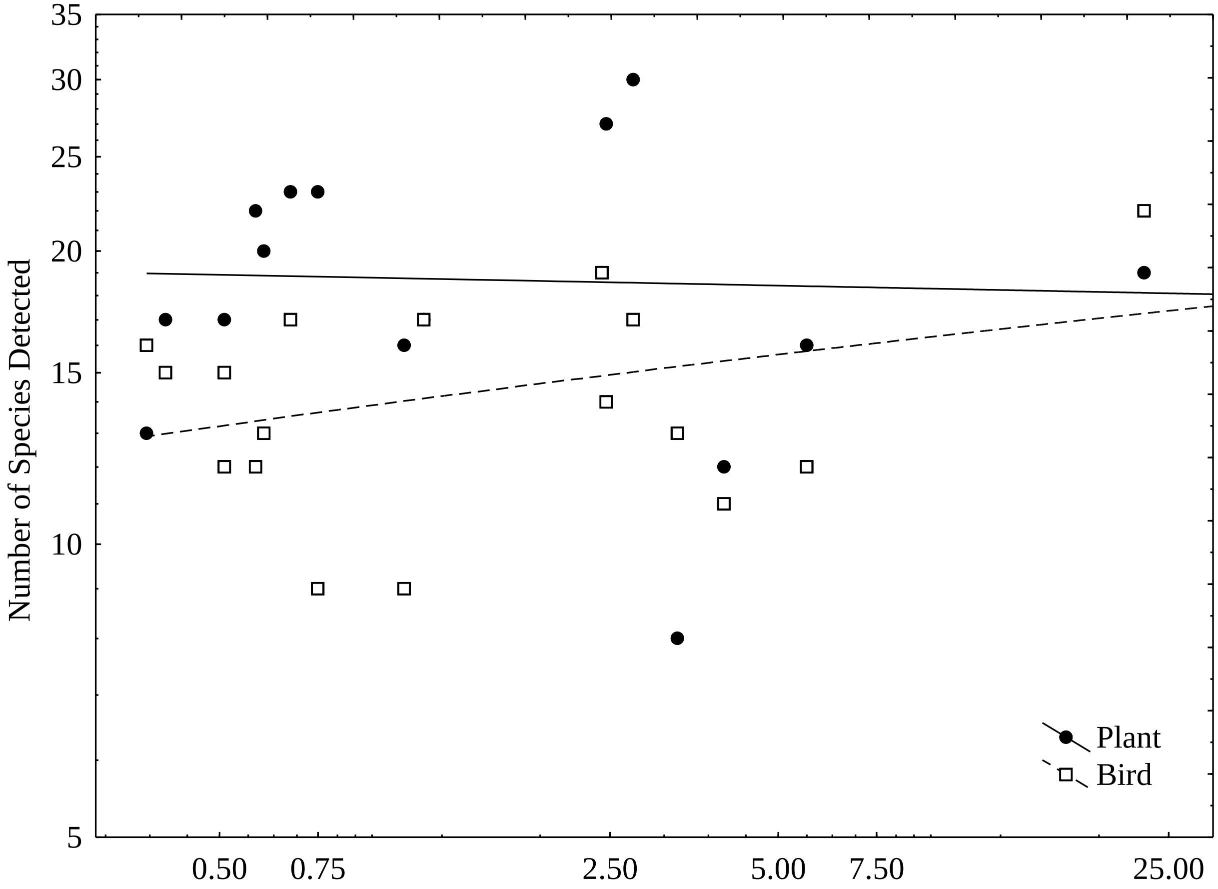

Figure. 2.3. Relationship between wetland area and plants (filled circles, LogPlantSpp=1.2562-0.0268LogArea, n=16, p=0.72) and avian (open squares, LogAvianSpp=1.1344 + 0.0614LogArea, n=17, p=0.27) species richness in constructed wetlands.

Table 2.3. Analysis of the covariance of the log transformed species-area relationship in natural and constructed wetlands for birds and plants. Significant p-values (<0.05) are indicated by an asterisk (*).

Wetland Class	Effect	SS	Degr. Of Freedom	MS	F	p
Natural, n=12	LogArea	0.03	1.00	0.03	2.20	0.15
	Taxon: Plant and Birds	0.83	1.00	0.83	68.25	0.00*
	Error	0.28	23.00	0.01		
Constructed, n=16	LogArea	0.00	1.00	0.00	0.16	0.69
	Taxon: Plants and Birds	0.10	1.00	0.10	6.10	0.02*
	Error	0.48	30.00	0.02		

Table 2.4. Separate slopes of the log transformed species-area relationship in natural and constructed wetlands for birds and plants. Significant p-values (<0.05) are indicated by an asterisk (*).

Wetland Class	Effect	SS	Degr. Of Freedom	MS	F	p
Natural, n=12	Taxon-LogArea	0.09	2	0.05	4.79	0.02*
	Taxon: Plants and Birds	0.79	1	0.79	80.97	0.00*
	Error	0.21	22	0.01		
Constructed, n=16	Taxon-LogArea	0.02	2	0.01	0.54	0.59
	Taxon: Plants and Birds	0.11	1	0.11	6.96	0.01*
	Error	0.46	29	0.02		

Discussion

General Census and Overall Species Richness in Natural and Constructed Wetlands

The avian point counts detected between 8 and 22 bird species at each wetland. Overall, a total or 71 bird species was surveyed across all wetlands. In 2006 and 2007, Dagenais (2009) detected 78 bird species overall at the constructed wetland sites, also using the point count method. Both my results and the results of Dagenais (2009) are lower than those of Gully (1983) who surveyed birds in the area between 1976 and 1983 using line transects year round. He detected 115 avian species (cited and summarized by Dagenais, 2009). My results appear to be comparable to those of Dagenais (2009) who suggested that avian species richness has declined over time. Based on the work of Dagenais (2009), a large proportion of the species that were not detected on oilsand leased sites were cavity or tree nesting species and many of the species that were detected in 2006-2007 but not in 1976-1983 were generalist species. Shrub nesters and corvid species did not exhibit as strong a decline. However, it must be noted that Gully (1983) surveyed avian species using line transects throughout the entire year whereas Dagenais (2009) and I surveyed only in summer and using the point county method and it is possible that this accounts for some of the differences between our studies and that of Gully (1983).

Marie-Claude Roy's survey (pers. comm.) detected 144 wetland plant species overall and between 8 and 38 different plant species at each wetland. There was a significant difference in the number of plant species detected between natural and constructed wetlands, with natural wetlands having on average 10 more plant species than constructed wetlands. I did not find a consistent difference in the relationship between species richness and wetland class for the birds. The lack of an overall difference is consistent with the findings of

Delphey and Dinsmore (1993) who compared avian species richness in natural and recently restored prairie pothole wetlands in Iowa. They also were unable to detect a difference in overall species richness. Birds of temperate marshes have high dispersal ability (Craig and Beal 1992) and so they are able to quickly colonize a habitat once suitable food sources are present. In fact, waterfowl will use a wetland habitat almost as soon as there is standing water (LaGrange and Dinsmore 1989, Sewell and Higgins 1991, Delphey and Dinsmore 1993, Vanrees-Siewert and Dinsmore 1996, Fairbairn and Dinsmore 2001) and this may explain why species richness is comparable between natural and constructed wetlands.

My inability to detect a difference in avian species richness could mean that natural and constructed wetlands are similar. However, I assessed only species richness, not species composition (but see Chapter 3). The constructed wetlands are in a disturbed landscape, which may limit natural colonization and may promote establishment of invasive species (Suding et al. 2004). The smallest of the constructed wetlands seemed to have greater species richness than the smallest of the natural wetlands, possibly reflecting the presence of invasive species or species that thrive in disturbed habitats. It is also possible that constructed wetlands have more rare species or simply early succession species compared to the later succession species that may be found in natural wetlands (see chapter 3). Hapner et al. (2011) examined the avian community change in restored wetlands over a 10-year period and found that species composition changed from primarily water-dependent species to old-field species, likely as a result of a decrease in the area of open water in the wetland and an increase in emergent vegetation. However, they did not compare the restored wetlands to natural wetlands in the region, although one might expect that constructed wetlands would resemble ‘young’ wetlands and the natural wetlands of the current study would be functionally equivalent to ‘old’ wetlands. However, all of the wetlands in the current study were aged 7 years or older and thus this community change may be relatively undetectable.

In contrast, except for weedy species, plants have relatively low dispersal ability. They depend on wind, water or animals for their dispersal and as a result it may take them longer to colonize a habitat. This may explain why the constructed wetlands would have fewer plant species than natural wetlands while no difference was found for birds. Furthermore, historical wetland revegetation practices involved natural colonization. Planting wetlands with numerous species at the time of construction may increase diversity in these young systems. Alternatively, landscape condition of the wetlands may be influencing the plant species richness (Rooney and Bayley 2001, Roy 2014). Within the oil sand constructed wetlands, Rooney and Bayley (2011) found that plant richness was lower in landscapes with greater mine-related disturbance, residential land cover and density of non-mining development and our results support these findings.

Species-Area Relationships in Plants and Birds

Plant species richness was independent of area in both natural and constructed wetlands whereas a significant species-area relationship was observed for birds in natural wetlands but not in constructed wetlands. The presence of a species-area relationship in birds in natural wetlands is expected and, in fact, birds are considered a model organism for studying species-area relationships (Benassi et al. 2007). The absence of an avian species-area relationship in the constructed wetlands is notable because it suggests that while species richness is comparable between natural and constructed wetlands, the constructed wetlands must differ from the natural wetlands in some way that obscures or overrides the species-area relationship.

There are three possible explanations as to why an avian species-area relationship was not observed in constructed wetland but was evident in natural wetlands;

(1) constructed wetlands are not sufficiently mature,

(2) constructed wetlands experience too much human disturbance, or

(3) area is not an important determinant of species richness in constructed wetlands

(4) there are not enough wetlands or a large enough range in sizes to detect the species area relationship.

In the MacArthur and Wilson theory of island biogeography (1967), island area and isolation cannot explain species richness until immigration and extinction rates have reached equilibrium, finally settling at a relatively constant value. If the wetlands are not yet mature, it is possible that they will have not had enough time to achieve a stable community. However, VanRees-Siewert and Dinsmore (1996) found that bird species richness did not vary with wetland age, although they noted that community composition did change. Alternatively, constructed wetlands may be subject to greater human disturbance (such as mining activities and noise pollution) and this prevents equilibrium and therefore obscures species-area relationships. In this scenario, constructed wetlands would have more species turnover than natural wetlands as disturbance would result in local wetland extinctions. It could also be that area *per se* isn't important for avian species richness at all and that some other variables, such as the quantity of arrangement of specific habitat types, explain more of the variation in species richness (Fairbairn and Dinsmore 2001). Finally, it is possible that there is not a large enough sample size or a great enough range of sizes to detect a significant species-area relationship. However, previous studies within wetlands have had smaller sample sizes (Tyser 1983, Craig and Beal 1992, Mamo and Bolen 1999, Benassi et al 2007, Craig 2008) and similarly small ranges of wetland size (Paracuellos 2006, Benassi et al 2007) and have still been able to detect species-area relationships therefore it is unlikely that this is way a significant species-area relationship was not detected for birds within the constructed wetlands.

Future studies should address these possible explanations by surveying the wetlands over several years. If species richness at each individual constructed wetland is more variable over time than turnover in natural wetlands of equivalent size one could infer that disturbance is masking species-area effects; the wetlands would not be reaching equilibrium and have a changing species richness. If species-richness is inconsistent at first but eventually achieves relatively constant numbers at each wetland then one could conclude that the constructed wetlands were too young in this study to detect species-area relationships. If species richness remains relatively constant as each constructed wetland ages over years it would suggest that the wetlands are at a richness equilibrium and thus area is not an important determinant of species richness on constructed wetlands. However, given that natural wetlands in the area do display a positive avian species-area relationship and that avian species-area relationships have been detected in other wetland and habitat studies, it is more likely that disturbance or time is preventing detection of an avian species-area relationship in constructed wetlands.

It is surprising that plant species richness was not significantly related to area in the natural wetlands. Presumably, these wetlands do not experience anthropogenic disturbance and should be old enough to have acquired a stable community, and Findlay and Houlahan (1997) documented a significant plant species-richness association within wetlands. However, studies of other habitats have failed to detect a plant species-area relationship (e.g., Steffan-Dewenter 2003), and it is possible that wetland area does not explain species richness for plants and other factors must be more important.

Trophic Species-Area

Our findings of richness patterns between taxa in both natural and constructed wetlands were consistent with the trophic theory (Holt 1999) in that producers exhibited overall higher species richness. However, this difference was more pronounced for the natural wetlands. The species-area relationship of consumers in natural wetlands was also stronger than that of producers as predicted by the stacked specialist model (Holt 1999). The differences were much weaker in constructed wetlands due primarily to the nonsignificance-of the species-area relationship for birds. Furthermore, constructed wetlands supported fewer plant species than their natural counterparts, especially in larger wetlands. As previously mentioned, the absence of a species-area relationship in constructed wetlands suggests either that they are too young, too disturbed, or that area is not an important variable for species-richness.

I did not find a plant species-area relationship in natural wetlands either. While Findlay and Houlahan (1997) did find a significant species-area relationship in temperate marshes, and Panitsa et al (2006) found them on islands of the Aegean Sea, Steffan-Dewenter (2003) examined trophic species-area relationships in fragmented forests and was not able to detect a plant species-area relationship.

Another possible explanation for the lack of a species-area relationship in plants in natural wetlands is that trophic island biogeography suggests that consumers can provide top-down pressure on lower trophic level species that may depress the strength of the species-area relationship (Holt et al. 1999). In this way, predators increase prey extinction and thus reduce richness directly and also through decreasing abundance and thus our ability to detect them. This is more likely to occur in larger wetlands, where predators are most likely to be present and persist. Panitsa et al. (2006) found that plant species-area relationships were weaker on islands that had grazing predators than those that didn’t, providing some support for this theory. However, given that the avian species-area relationship in the current study was weak relative to other studies and if one accepts that predators must have a stronger relationship than prey, plants would have a very minor species-area relationship in natural wetlands to start with, and top-down effects may have further weakened it. However, birds are unlikely to exhibit a strong enough foraging pressure upon the wetland plant community to depress the plant species-area relationship.

Conclusions and Recommendations

Given that the species-area relationship is found worldwide and across taxa, wetland area is clearly an important variable in determining species richness, and this must be taken into account when conserving and constructing wetlands. Larger wetlands not only can support more species but also help prevent extinction by allowing greater abundance. This study provides further evidence for wetlands acting as habitat islands by documenting a species-area relationship in birds among the natural wetlands. The results of this study suggest that constructed wetlands may support similar numbers of species as natural wetlands overall but that the species richness of a constructed wetland is not tied to the wetland area as it is for natural wetlands. This may reflect the age of the constructed wetlands, the amount of disturbance they experience, or perhaps other factors better explain species richness. Assessing habitat characteristics and surveying the wetlands over several years will help elucidate trends in avian species richness in the constructed wetlands. I address the possibility of habitat effects in the next chapter.

Plant species richness consistently exceeded that of avian species richness across all wetland sizes, providing moderate support for trophic effects on the species-area relationship. However, plant richness was independent of wetland area in natural and constructed wetlands. A few studies have failed to detect or found a negative species-area relationship in plants in fragmented habitats (Steffan-Dewenter 2003, Jonsson et al. 2009) and perhaps plant species richness is better explained by other factors.

Overall I find that producer richness typically exceeds consumer richness on both natural and constructed wetlands. Greater producer richness provides habitat and food resources for consumers while also allowing for increasing consumer specialists. In order to increase species richness at constructed wetlands across all different taxa, I recommend allowing for natural colonization but also planting a wide range of native wetland plants.

To get a full understanding of the drivers of species richness in natural and constructed wetlands, future work should include surveys of the invertebrate community as well as plant and avian species. Analysis of species-area relationships for all of these taxa are needed as well as what the relationship these taxon have to other habitat variables such as wetland shape or water chemistry.

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CHAPTER III

THE INFLUENCE OF ENVIRONMENTAL COVARIATES ON AVIAN SPECIES-AREA RELATIONSHIPS IN NATURAL AND CONSTRUCTED WETLANDS

Introduction

The species-area relationship is one of the most dependable phenomena in ecology (Schoener 1976). It has been demonstrated globally (Preston 1960) and across taxa. For example, Findlay and Houlahan (1997) observed significant species-area relationships in birds, plants, herptiles and mammals of eastern Canadian wetlands. Similarly, Guilhaumon et al. (2012) observed species-area relationships in benthic invertebrates in lagoons in Italy. The species-area relationship has been observed on islands as well as among fragmented and insular habitats on the mainland (Brose 2001). Compared to other habitat types, relatively few studies have examined species-area relationships in naturally patchy (Paracuellos and Tellerìa 2004, Guadagnin and Maltchik 2007) wetland habitats (Benassi et al. 2007), even though wetlands are a highly threatened ecosystem (Benassi et al. 2007) and perform many important ecological functions (e.g. providing distinctive habitat, controlling sediment and water quality etc.). In addition to the decline in wetland extent and number and the degradation of existing wetlands, wetland bird species diversity is also in decline in North America (Eddleman et al. 1988, Conway and Eddleman 1994, Sauer et al. 2008) and this is likely due to the deterioration and loss of habitat (Steen et al. 2006).

Species-area relationship studies that have been performed on wetland bird species have demonstrated significant positive species-area relationships (Burger et al. 1982, Tyser 1983, Brown and Dinsmore 1986, Gibbs et al. 1991, Craig and Beal 1992, Celada and Bogliani 1993, Findlay and Houlahan 1997, Mamo and Bolen 1999, Báldi and Kisbenedek 2000, Colwell and Taft 2000, Riffell et al. 2001, Paracuellos and Telleria 2004, Shriver et al.

2004, Paracuellos 2006, Benassi et al. 2007, Guadagnin and Maltchik 2007, Craig 2008, Guadagnin et al. 2009, Gonzalez-Garjardo et al. 2009, Tsai et al. 2012), with z-values ranging from 0.23 to 0.94 (although not all studies have reported z-values). In addition, some bird species exhibit area sensitivity in that they are not detected in habitats smaller than a given size (Brown and Dinsmore 1986; Naugle et al. 1999; Riffell et al. 2001, Smith and Chow-Fraser 2010). It is often unclear, however, whether the species-area relationship is a feature purely of wetland area or of the greater habitat heterogeneity associated with larger areas (Wiens 1989). That is to say, larger area may directly support greater species richness (because a large extent of area may sustain larger populations, thus reducing the likelihood of extinction through random fluctuations), or it may have an indirect effect on richness through its correlation with habitat heterogeneity (Guadagnin et al. 2009) (i.e. greater heterogeneity may allow more species because there is a greater diversity of resources, facilitating successful immigration). Many researchers have experienced difficulty in trying to separate the effects of habitat area and heterogeneity (Wiens 1989), and both habitat area (Benassi et al. 2007) and habitat structure and complexity have been documented to be important to avian ecology (MacArthur 1961, MacArthur et al. 1962, Cody 1981, 1985).

Many habitat factors have been shown to influence avian richness. Larger wetland area is correlated with greater avian species richness (e.g., Brown and Dinsmore 1986) and several studies have shown that proximity to additional habitat can support greater species richness. Craig and Beal (1992) found that wetlands that had nearby wetland habitat were more species rich, likely due to increased foraging opportunities provided by nearby wetlands; and Alsfeld et al. (2010) found that proximity to forest was important to avian species richness. Wetland bird diversity is positively associated with vegetation diversity and spatial complexity (e.g., Gibbs et al. 1991), while housing development (Friesen et al. 1995) and the presence of roads (Findlay and Houlahan 1997, Forman and Alexander 1998) can negatively influence the species richness of birds in wetlands. It may be most beneficial for conservation and restoration plans whose goal is to maximize avian biodiversity to consider all of these habitat characteristics when examining species area relationships (Ricklefs and Lovette 1999, Panitsa et al. 2006).

The boreal forest of north eastern Alberta is composed of areas that are up to 65% wetland habitat (Raine et al. 2002). Disturbance and land-clearing to conduct oil sands mining has resulted in extensive loss of wetland habitat. Further, proximity to disturbance has been shown in many studies to reduce wetland biodiversity (Alsfeld et al. 2010). Oil sands industry partners and researchers are collaborating to re-establish the pre-disturbance wildlife habitat types and quantities in the post-mining landscape, and restore mining lease sites to their original level of functionality (Oil Sands Wetland Working Group 2000). It has been suggested that species-area relationships may have practical applications and be used to set conservation size guidelines in order to protect biodiversity (May 1975, Diamond and May 1976, Rosenzweig 1995, Vreugdenhil et al. 2003, Desmet and Cowling 2004) and thus species-area relationships may be a valuable tool in this reclamation process by providing wetland size guidelines for creating wetlands capable of sustaining an avian community comparable to those found naturally.

In this study, my objective was to conduct avian surveys at constructed and natural boreal forest wetlands that vary in area, habitat heterogeneity, isolation from other wetland habitats and various habitat characteristics related to avian diversity to determine the extent to which species richness is influenced by any one or all of these components. I expected that knowledge of the characteristics of other environmental factors would increase the amount of variability explained.

If natural and constructed wetlands vary in habitat characteristics, one might expect to find species composition differences among wetlands that differ in relative proportions of each habitat type. To address this prediction we examined trends in species composition (presence/absence) among wetlands, and assessed whether groups of taxa associated differentially with the natural and constructed classes of wetlands. This research will provide further insight into the growing body of evidence for species richness-habitat relationships in wetlands as well as contribute to the conservation and reclamation of sustainable wetland habitats comparable to those found naturally.

Methods

Study Sites

Surveys were performed near Fort McMurray, Alberta on land leased by Suncor Energy Inc. and Syncrude Canada Ltd. as well as at offsite locations (Fig.2.1). The study area was approximate 75 km from north to south and about 20 km from west to east. Surveys took place between 19 June and 5 July 2011 and 16 May and 8 June 2012. In 2011, 18 marsh-like wetlands were surveyed. Wetlands were classified as either ‘constructed’ (n=8, between 2 and 40 years old) or ‘natural’ (n=8, between 29 and >50 years old). In 2012, surveys were performed at 31 marsh-like wetlands of various sizes - 17 constructed and 14 natural. Constructed wetlands ranged in age from 7 to 41 years at time of sampling and had been built (or had formed opportunistically) on cleared, leased mining lands. Most natural wetlands were situated on crown land. Most were of indeterminate age (appearing on maps or aerial photos 30 to >50 years old). Natural wetlands situated on the oilsands lease lands must have existed prior to mine development; they are not opportunistic.

Wetland Area and Distance Measures

I used Google Earth Pro software (Google Inc. 2012) to obtain aerial images of the wetlands. Images used were the highest quality available, and were collected in July and August in the years 2008-2010. I measured wetland perimeter (m) and area (ha) for both the emergent vegetation and open water areas of the wetland using the Polygon Measure tool. The open water zone was the portion of the wetland in which water was visible in aerial view of Google Earth images. The emergent vegetation zone was the portion of the wetland that contained vegetation that was raised out of the water and appeared distinct from terrestrial vegetation. The two zones were clearly visible from the aerial images. The total wetland area (ha) was calculated as the sum of the open water and emergent vegetation zones. Additionally, I measured distances (m) of each wetland from its edge to the nearest edge of wetland, water body (which occasionally was also the nearest wetland), disturbance (road, tailings pond, building, etc.), trafficked road (which was occasionally also the nearest disturbance) and forest.

Habitat Surveys

A visual habitat survey was conducted at each wetland from the location and vantage point of the first avian point count to determine any potentially important relationships between the habitat components and avian richness. I used the survey approach outlined in *Prairie & Parkland Marsh Monitoring Program – Habitat Description Form* (Bird Studies Canada 2010) to record wetland habitat data. The survey contains three major sections: percent coverage of major wetland habitats (herbaceous emergent vegetation cover, patches of open water, exposed substrate (mud/sand/rock), trees, and shrubs), percentage of open water covered by floating plants (including free floating and those rooted to the wetland bottom) and dominant herbaceous emergent vegetation (non-woody species that are rooted in the marsh bottom and rise above the water level). A rough sketch of the wetland was also completed.

Habitat heterogeneity of the survey portion of each wetland was estimated by summarizing variability among the wetland habitat classes using Simpson's Index (SI; Simpson 1947) as described by Craig (2008) and taking its complement – the Gini-Simpson index (Peet 1974),

Simpson's Index = $\sum (p_i^2)$

Gini- Simpson Index = 1- Simpson's Index = 1- $\sum (p_i^2)$

where p_i is the relative proportion of the overall area of habitat class i as estimated from the habitat survey of relative area (percent) of 5 cover types (water & floating plants, unvegetated land, herbaceous emergent vegetation, shrubs, trees).

Avian Surveys

I used the 10-min point count method (Bibby 2000) to survey avian communities, noting the presence of all birds seen or heard during the survey period, and the number of individuals of a species when possible. Point counts were performed between sunrise (approximately 0400 h) and 1000 h MDT. Point counts were only conducted in conditions of no rain and low winds (<15 km/h). I performed point counts at three locations in each wetland. Where possible, each point count station was at least 200 m away from its nearest neighbour. When a wetland was not large enough to situate survey points 200 m apart I attempted to maximize the distance between stations. Subsequently, each species was assigned to one or more functional or ecological groups according to common understanding of its typical ecological habits – waterfowl, shorebird, marsh resident, lake resident, pond resident, grassland, shrub-forest, or woodland. Species were also classified as being either "aquatic" (belonging to one or more of the first 5 classes, or "terrestrial" (belonging to one or more of the latter 3 classes). Finally species were classified as being 'generalists' and/or characteristic of 'disturbed' habitats. Species could be listed in multiple groups where appropriate.

Statistical Analyses

Statistical analyses were conducted using STATISTICA software (Version 7.1, Statsoft, Inc., Tulsa, OK). I determined the mean and range of number of bird species detected overall as well as the mean and range of total wetland area (emergent vegetation + open water). Simple linear regression analyses of the log transformed data for species richness vs. log-transformed wetland area were performed to estimate the species-area relationship for natural and for constructed wetlands. The resulting regression coefficients were the z-scores for each relationship. I also regressed the log transformed species richness against the measure of habitat heterogeneity calculated using the Gini-Simpson index. Null hypotheses for these relationships were rejected at a one-tailed alpha = 0.05 based on the postulate that species richness is expected to increase as a function of larger area and greater habitat heterogeneity.

I performed Principal Components Analysis (PCA) to summarize the variables representing habitat characteristics to a smaller set of statistically independent principal components. These were then used as covariates in the interpretation of the species-area relationship. The PCA was performed using a correlation matrix of the log-transformed raw data except for percent cover of open water, percent cover of emergent vegetation and habitat heterogeneity, which were normally distributed in their original form. Components were rotated using Varimax raw rotation. One representative variable was selected as being representative of each Principal Component. This was the variable having the highest loading (i.e., highest correlation) on the Principal Component. The representative variables were then used as covariate independent variables, together with overall wetland area, and habitat heterogeneity in a forward stepwise multiple regression analysis of the avian species richness for constructed and natural wetland classes. The variables "percent cover of trees", "percent cover of shrubs" and "percent cover of mud, sand and rock" were not included in the analysis because their values did not vary among the wetlands sampled.

I used non-metric multidimentional scaling (NMDS) analysis using PC-ORD (MJM Software, Gleneden Beach OR) to develop composite summaries (NMD axes) that would represent the species composition of natural and constructed wetlands. Species were classified as present or absent at each wetland. Only species that were observed at four or more wetlands were included in the analysis (46 species; Appendix V). An among-wetland distance matrix was created using Sorensen's index (Bray-Curtis distance), which was then imported into the PC-ORD program. One-way ANOVA was performed to compare the means of constructed and natural wetland scores for each NMD axis identified by the ordination

Associations between NMD axes and functional avian groups were determined by calculating a rectangular correlation matrix relating the loadings of each species' NMD scores for each wetland and the species membership in a functional group.

We performed exploratory analysis by plotting wetland NMD axis scores against the principal component variables (representing wetland size, disturbance, percent cover of emergent vegetation and isolation from the nearest water body) for each wetland to assess how these environmental features influenced trends in species composition, and whether these differed systematically between natural and constructed wetlands.

Results

General Census and Species-Area Relationships: General census results as well as a comparison of means and the avian species-area relationships for natural and constructed wetlands were described in detail in Chapter 2. In short, there was no significant difference in the mean number of species detected between natural and constructed wetlands. Natural wetlands displayed a positive species-area relationship while constructed wetlands did not (as shown in the previous chapter; Table 2.2, Fig. 2.3, Fig. 2.4).

Richness – Habitat Heterogeneity Relationships: Simple regression revealed that species richness was independent of habitat heterogeneity for natural wetlands (Table 3.1; one-tailed p=0.14; n=14, R^2 0.09). The relationship was marginally significant for constructed wetlands (Table 3.1; one-tailed p=0.025, n=17, R^2=0.23).

Principal Component Analysis: Principal Component Analysis identified four principal components (PCs) with eigenvalues >1.0 that together accounted for 77% of the total variation in environmental variables among wetlands (Table 3.2).

Table 3.1. Regression analysis of relationship between species richness and habitat heterogeneity in natural (R^2=0.09, LogAvianSpp= 1.0037 + 0.2690HabitatHeterogeneity) and constructed wetlands (R^2=0.23, LogAvianSpp = 1.0095+0.3697HabitatHeterogeneity). Significant p-values (<0.05) are indicated by an asterisk (*).

Wetland Class		SS	Degr. of	MS	F	P
Natural, n=14	Habitat Heterogeneity	0.02	1.00	0.02	1.25	0.28
	Error	0.23	12.00	0.02		
Constructed, n=17	Habitat Heterogeneity	0.04	1.00	0.04	4.51	0.05*
	Error	0.14	15.00	0.01		

Table 3.2. Principal component loadings of the raw varimax rotated principal component analysis. Variables with correlations greater than |0.75| are indicated by an asterisk (*). Variables that have the highest correlation on each principal component are in bold.

Variable	PC-I	PC-II	PC-III	PC-IV
LogArea	**0.94***	0.24	0.04	0.1
LogPerEmerg	0.86*	0.18	0.05	0.2
LogAreaEmerg	0.83*	0.11	0.07	-0.13
LogArea OW	0.80*	0.01	0.22	0.24
LogAge	0.73*	-0.18	-0.33	-0.4
PctOpenWater	-0.13	**-0.92***	0.05	0.03
Habitat Heterogeneity	0.35	0.79*	-0.19	0
PctEmergentVeg	-0.01	0.79*	0.31	-0.11
LogNrForest	-0.31	0.41	0.2	0.29
LogNrDisturb	0.14	-0.12	**0.92***	-0.04
LogNrRoad	-0.02	0.13	0.91*	-0.17
LogNrWater	-0.06	0.02	-0.17	**0.81***
LogNrWetl	0.38	-0.21	-0.18	0.75*
Explained Variance	3.88	2.47	2.07	1.63
Proportion of total Variance	0.3	0.19	0.16	0.13
Cumulative Variance Explained	31.21	50.51	65.72	77.26

Scores of PC-I were positively correlated with measures of open water area, percentage emergent vegetation, area of emergent vegetation, and overall area of the wetland. Thus, PC-I was a composite measure of “wetland size”. Wetland age was also highly correlated with the size of the wetland, likely because the natural and older wetlands tended to be the larger ones. I used the total wetland area as the representative value for this PC in the multiple regression analysis.

Relative area (percentage) of open water was negatively correlated with scores of PC-II, whereas percent cover of herbaceous emergent vegetation and habitat heterogeneity were positively correlated, meaning that when there were large amounts of herbaceous emergent vegetation there tended to be less open water in the wetland. Distance to the nearest forest correlated most highly but only modestly (0.41) with this scores of this PC. PC-II served as a composite surrogate for ‘extent of vegetation’. Relative area of open water had the highest correlation value and was used for the multiple regression analysis.

Scores of PC-III were positively correlated with distance of a wetland edge from the nearest road regularly used by traffic (heavy haulers, light trucks, etc.) and distance from the nearest disturbance (of any type). Both variables are measures frequency of human activity (noise and motion) and cleared land; and trafficked roads were often the nearest disturbance to the wetland. Therefore, PC-III is a composite measure of “degree of disturbance”. Distance from the nearest disturbance was used in the multiple regression analysis.

The distance between the wetland edge, the nearest water body and the distance to the nearest wetland were both negatively associated with PC-IV, largely because the nearest water body was almost always another wetland rather than a lake or the Athabasca River. Therefore, PC-IV was a composite variable summarizing ‘isolation’. Distance to the nearest water body was selected.

The following variables were Log-transformed and used in the multiple regression analyses: total area of the wetland, percent cover of open water, distance to the nearest disturbance and distance to the nearest water body.

Multiple Regression of Environmental Variables against Species Richness: Forward stepwise multiple regression analysis of the data for natural wetlands revealed a significant relationship overall ($p<0.02$, Table 3.3). Four variables were included in the final model, explaining 61% of the variability overall. The equation of the line was

$$\text{Log(Richness)} = 0.69 + 0.05\,\text{Log(TotalArea)} + 0.10\,\text{Log(NearestDisturbance)} + 0.14\,\text{Log(NearestWaterbody)}.$$

Area of the total wetland explained the greatest portion of the variability (partial $R^2=0.34$), and distance to the nearest disturbance was the second best predictor and a significant relationship (partial $R^2=0.18$). Distance to the nearest water body explained 8% of the variation in species richness. Thus, wetlands with the greatest species richness were larger (across all measures of size, as well as age), tended to be remote from disturbance (typically trafficked roads) and further from other bodies of water, especially other wetlands.

Avian richness in the constructed wetlands was not significantly related to any of the variables analyzed (Table 3.3). The strongest relationship ($R^2=0.2$) was with relative area of open water (and thus greater cover of emergent vegetation and higher habitat heterogeneity).

Species Composition Groupings: A 3-dimensional non-metric multidimentional scaling analysis summarized overall variation in species presence/absence among wetland with acceptable distortion (Table 3.4; stress =0.19).

Table 3.3. Results of a forward stepwise multiple regression of log species richness vs. the single environmental variables most highly correlated with each principal component in natural wetlands (n = 14, $F_{[3,10]} = 5.14$, $p<0.02$) and constructed wetlands (n=17, p=0.14, $F_{[3,13]}=2.19$). Significant p-values (<0.05) are indicated by an asterisk (*).

Wetland Class		Beta	Std.Err.	B	Std.Err.	t(10)	Partial R^2
Natural, n=14	LogAreaTotal	0.29	0.24	0.05	0.04	1.20	0.34*
	LogNrDisturbance	0.59	0.23	0.10	0.04	2.57*	0.18
	LogNrWaterbody	0.35	0.24	0.14	0.10	1.45	0.08
	Total						0.61
Constructed, n=17	PctOpenwater	-0.37	0.23	-0.001	0.00	-1.59	0.20
	LogAreaTotal	0.34	0.24	0.07	0.05	1.40	0.06
	LogNrDisturbance	-0.31	0.24	-0.04	0.03	-1.27	0.08
	Total						0.34

Table 3.4. Correlation matrix relating loadings of each of 46 bird species on an NMD axis to their membership in functional groups

	NMD Axis 1	NMD Axis 2	NMD Axis 3	Generalist	Disturbance	Waterfowl	Shorebird	Marsh	Lake Pond	All Aquatic	Grassland	Shrub-Forest	Woodland	All Woodland	All Terrestrial
BWTE	0.61	-0.03	0.23	1	1	1	0	0	1	1	0	0	0	0	0
VESP	0.61	-0.14	-0.09	0	1	0	0	0	0	0	1	0	0	0	1
BUFF	0.54	0.16	-0.15	1	1	1	0	0	1	1	0	0	0	0	0
LEYE	0.50	0.05	0.31	1	1	0	0	1	0	1	0	0	0	0	0
AMRO	0.47	-0.17	-0.24	1	1	0	0	0	0	0	0	0	1	1	1
GRYE	0.47	0.07	0.17	1	1	0	0	1	0	1	0	0	0	0	0
SPSA	0.44	0.15	0.42	1	1	0	1	0	0	1	0	0	0	0	0
BOGU	0.43	0.03	0.09	1	1	0	0	0	1	1	0	0	0	0	0
WISN	0.41	0.27	0.16	1	1	0	0	1	0	1	0	0	0	0	0
GWTE	0.36	0.15	0.11	1	1	1	0	1	0	1	0	0	0	0	0
RNDU	0.26	0.11	0.14	1	1	1	0	0	1	1	0	0	0	0	0
SWSP	0.12	0.08	0.07	0	1	0	0	1	0	1	0	0	0	0	0
AMWI	0.27	0.55	0.17	1	1	1	0	0	1	1	0	0	0	0	0

REVI	-0.45	0.52	0.09	1	0	0	0	0	0	0	0	0	1	1	1
AMCR	0.09	0.53	-0.14	1	0	0	0	0	0	0	0	0	1	1	1
YWAR	-0.33	0.38	-0.09	0	0	0	0	0	0	0	0	0	1	1	1
HEGU	0.12	0.33	-0.17	1	1	0	1	0	0	1	0	0	0	0	0
TRSW	0.14	0.28	0.14	1	1	0	0	0	0	0	0	0	0	0	0
AMCO	0.12	0.23	0.21	1	1	1	0	0	1	1	0	0	0	0	0
COYE	0.13	0.20	-0.04	0	1	0	0	0	0	0	0	1	0	0	1
SORA	-0.05	0.48	0.68	1	1	0	0	1	0	1	0	0	0	0	0
RWBL	0.10	0.01	0.62	1	1	0	0	1	0	1	0	0	0	0	0
MALL	0.39	0.32	0.50	1	1	1	0	0	1	1	0	0	0	0	0
KILL	0.16	-0.25	0.49	1	1	0	0	0	0	0	1	0	0	0	1
NOSH	-0.15	0.30	0.46	1	1	1	0	1	0	1	0	0	0	0	0
BHCO	0.25	-0.45	0.39	0	1	0	0	0	0	0	1	0	0	0	1
COGR	0.00	-0.25	0.28	0	1	0	0	0	0	0	0	0	1	1	1
HOGR	-0.22	0.08	0.28	1	1	1	0	0	1	1	0	0	0	0	0
COLO	-0.16	0.08	-0.07	1	0	1	0	0	1	1	0	0	0	0	0

CAGO	0.02	0.01	0.00	1	1	1	0	1	0	1	0	0	0	0	0
COGO	0.25	-0.05	0.28	1	1	1	0	0	1	1	0	0	0	0	0
LCSP	-0.27	0.05	0.25	0	0	0	0	0	0	0	1	0	0	0	1
LESC	-0.33	-0.06	0.29	1	1	1	0	0	1	1	0	0	0	0	0
MAWA	-0.29	-0.18	0.16	0	0	0	0	0	0	0	0	0	1	1	1
BOCH	-0.36	-0.27	0.12	0	0	0	0	0	0	0	0	0	1	1	1
SOSP	-0.40	0.07	0.35	1	1	0	0	0	0	0	0	0	1	1	1
CCSP	-0.51	0.45	-0.11	0	1	0	0	0	0	0	1	0	0	0	1
BBMP	-0.57	-0.22	-0.06	1	1	0	0	0	0	0	0	0	1	1	1
CORA	-0.06	-0.25	-0.04	1	1	0	0	0	0	0	0	0	1	1	1
CANV	-0.20	-0.34	-0.14	1	1	1	0	0	1	1	0	0	0	0	0
NOFL	-0.24	-0.37	-0.11	1	0	0	0	0	0	0	0	0	1	1	1
MYWA	-0.28	-0.53	0.11	0	0	0	0	0	0	0	0	0	1	1	1
WTSP	-0.14	-0.56	0.11	1	1	0	0	0	0	0	0	0	1	1	1
SASP	0.03	-0.67	0.32	0	1	0	0	0	0	0	1	0	0	0	1
CHSP	-0.19	0.03	-0.46	1	1	0	0	0	0	0	0	0	1	1	1

SWTH	0.05	-0.19	-0.59	0	0	0	0	0	0	0	0	0	1	1	1

Table 3.5. Correlation of species with NMD scores based on habitat functional groups for (n=46, p<0.05).

	Generalist Spp	Disturbance Spp	Waterfowl	Shorebird	Marsh	Lake Pond	All Aquatic	Grassland	Shrub-Forest	Woodland	All Woodland	All Terrestrial
NMD Axis 1	0.22	-0.15	0.16	0.16	0.23	0.22	0.44*	-0.00	0.04	-0.49	-0.50*	-0.46
NMD Axis 2	0.29*	-0.10	0.19	0.16	0.23	0.14	0.36*	-0.25	0.09	-0.24	-0.28	-0.40*
NMD Axis 3	0.15	0.03	0.12	0.00	0.32*	0.08	0.32*	0.13	-0.09	-0.40	-0.42*	-0.33

Species whose presence was positively correlated with scores of NMD-1 tended to be marsh and wetland birds (Table 3.4, Table 3.5) - Blue-Winged Teal, Green-Winged Teal, Bufflehead, Ring-necked Duck, Lesser and Greater Yellowlegs, Spotted Sandpiper, Wilson Snipe, and Bonaparte's Gull; also Vesper Sparrow and American Robin), whereas those whose presence was negatively associated were woodland species (Magnolia Warbler, Boreal Chickadee, Song Sparrow, Clay-Coloured Sparrow, LeConte's Sparrow and Black-Billed Magpie; also Lesser Scaup (Table 3.4, Table 3.5).

NMDS axis 3 described a different suite of aquatic species whose presences correlated positively (Sora, Red-winged Blackbird, Mallard, Killdeer, Northern Shoveler, Horned Grebe, Common Goldeneye; also Common Grackle) and terrestrial species whose presences were negatively correlated (Chipping Sparrow, Swainson Thrush; Table 3.4, Table 3.5).

Species whose presence correlated with scores of NMD axis 2 were primarily terrestrial. Widgeon, Red-Eyed Vireo, Crow, and Yellow Warbler; also Herring Gull, occurrence was positively associated with high scores of NMD-2 and appear to be generalist species, whereas Brown-headed Cowbird, Canvasback, Northern Flicker, Myrtle Warbler, White-throated Sparrow, Savannah Sparrow and Common Raven occurrence was negatively correlated (Table 3.4, Table 3.5).

The occurrence of several aquatic species (American Coot, Common Loon, Canada Goose, Common Yellowthroat, Swamp Sparrow) was independent of any of the NMD axes (correlations <0.25 with any axis; Table 3.4).

Patterns in Composition across Wetland Types: There were clear, statistically significant differences in the scores of the NMD axes summarizing avian community composition between natural and constructed wetlands. Natural wetlands tended to support species whose presence was correlated with positive scores of NMD axis 1 (water-related birds), and negative scores of NMD axis 2 (terrestrial species, Fig. 3.1). In contrast, constructed wetlands were dominated by species whose presence correlated to positive scores of NMD Axis 2 (woodland species) and negative values of NMD Axis 1. The differences in mean scores between natural and constructed wetlands were statistically significant for both NMD Axis 1 (1-way ANOVA, $p<0.01$; Fig. 3.2) and NMD Axis 2 (1-way ANOVA, $p < 0.05$). There was no difference in mean scores for NMD Axis 3 ($p > 0.5$).

Patterns in Composition across Environmental Gradients

I plotted the wetland scores of NMD axes against their principal component scores to subjectively evaluate trends in species associations across the environmental gradients. Natural wetlands, which tended to have positive scores on NMD Axis 1 tended to be larger and older (associated with positive scores of PC-1) than constructed wetlands (Fig. 3.3). Species composition on NMD Axis 1 in natural and constructed wetlands also tended to be separated with respect to degree of disturbance (PC-3; Fig. 3.4) with natural wetlands moving from more NMD-1 negative to more NMD-1 positive species as the level of disturbance decreased. Constructed wetlands scored lower in proximity to disturbance overall and generally were NMD-1 negative. Constructed wetlands did not appear to vary with respect to the amount of open water (PC-2; Figure. 3.5) while natural wetlands appeared support more NMD-1 negative species as the amount of open water decreased. Natural and constructed wetlands did not seem to differ with respect to the distance to the nearest water body (PC-4). It appears as though for wetlands of equal size and isolation (distance to the nearest water body), natural wetlands tended to contain more NMD-1 positive species

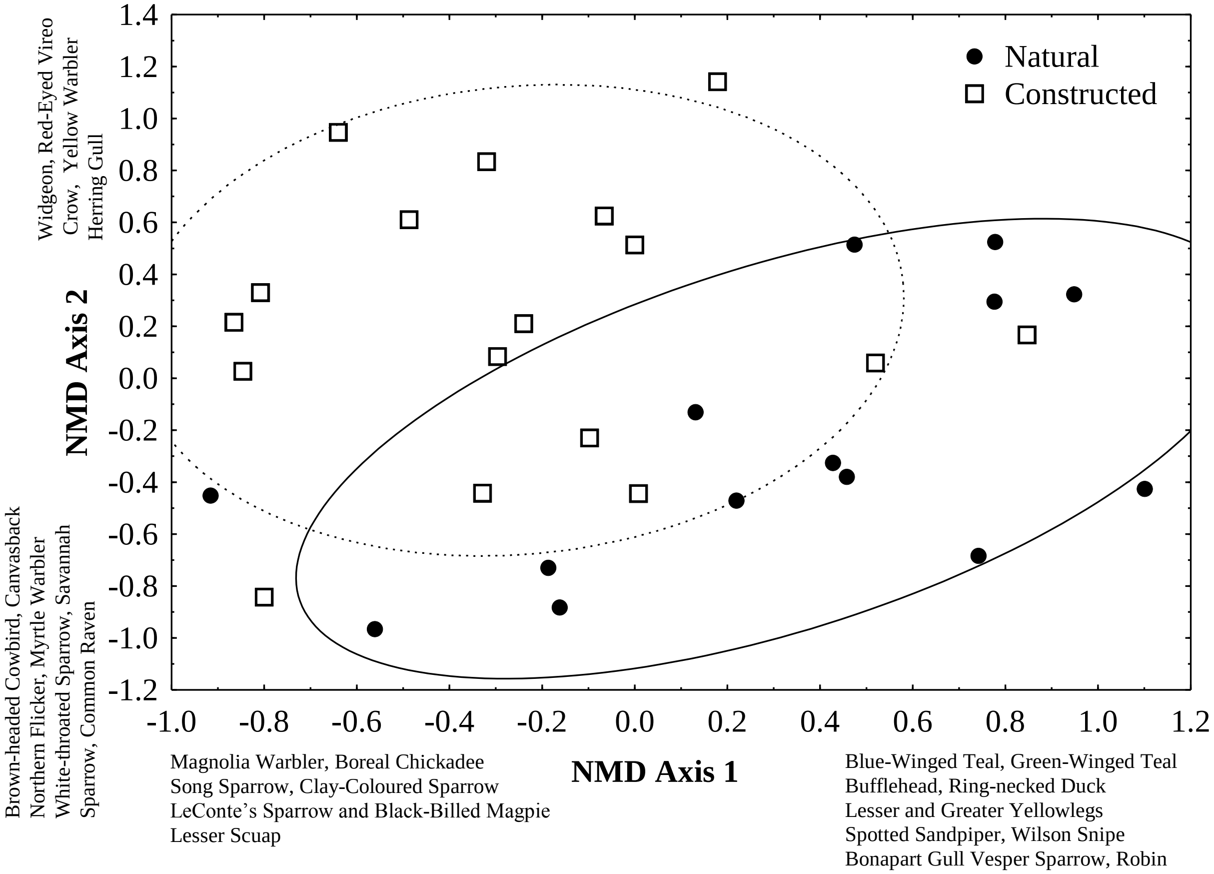

Figure 3.1. Species composition associations to natural and constructed wetlands from NMD Axis 1 and NMD Axis 2. Ovals represent 70% confidence ellipses.

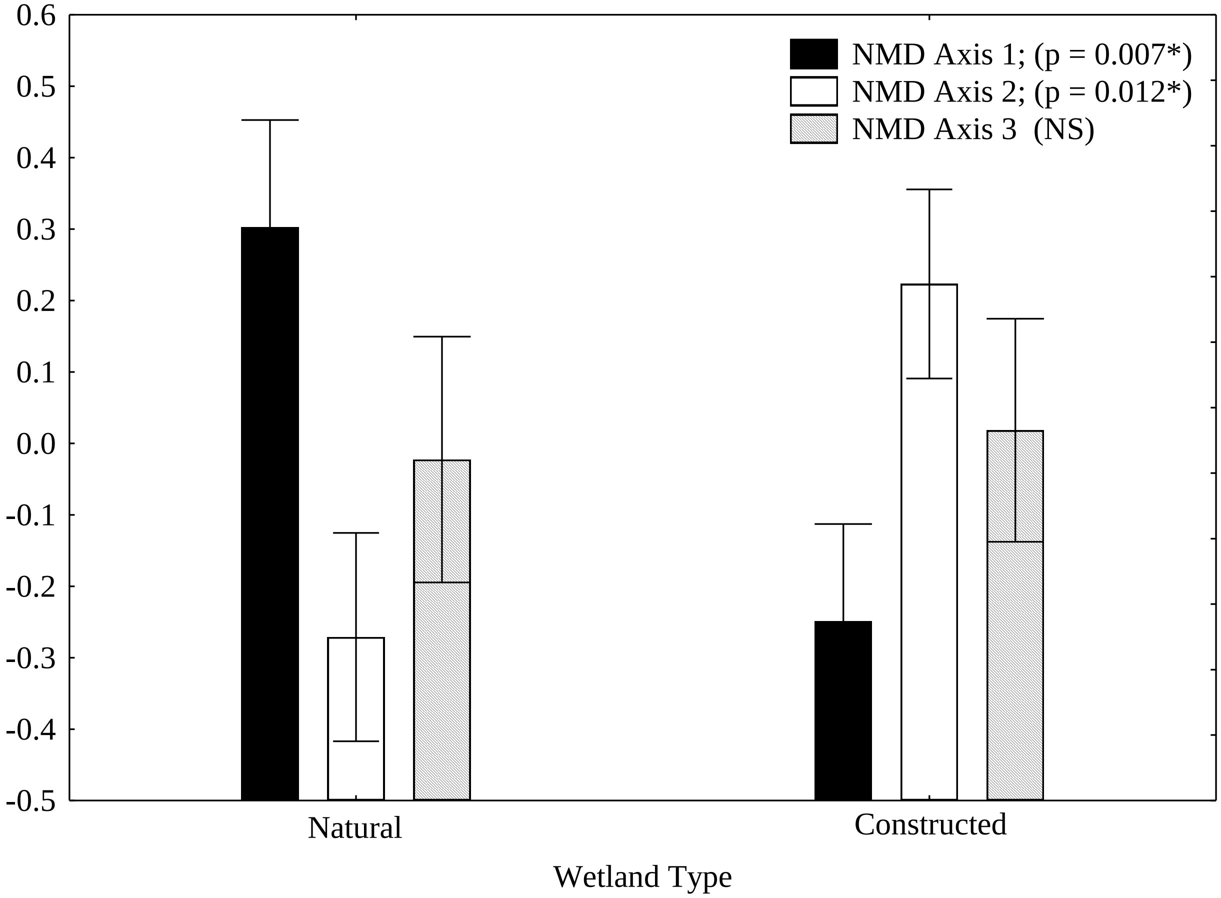

Figure 3.2. Mean (±SE) NMD Axis scores of natural (n=12) and constructed (n=16) wetlands.

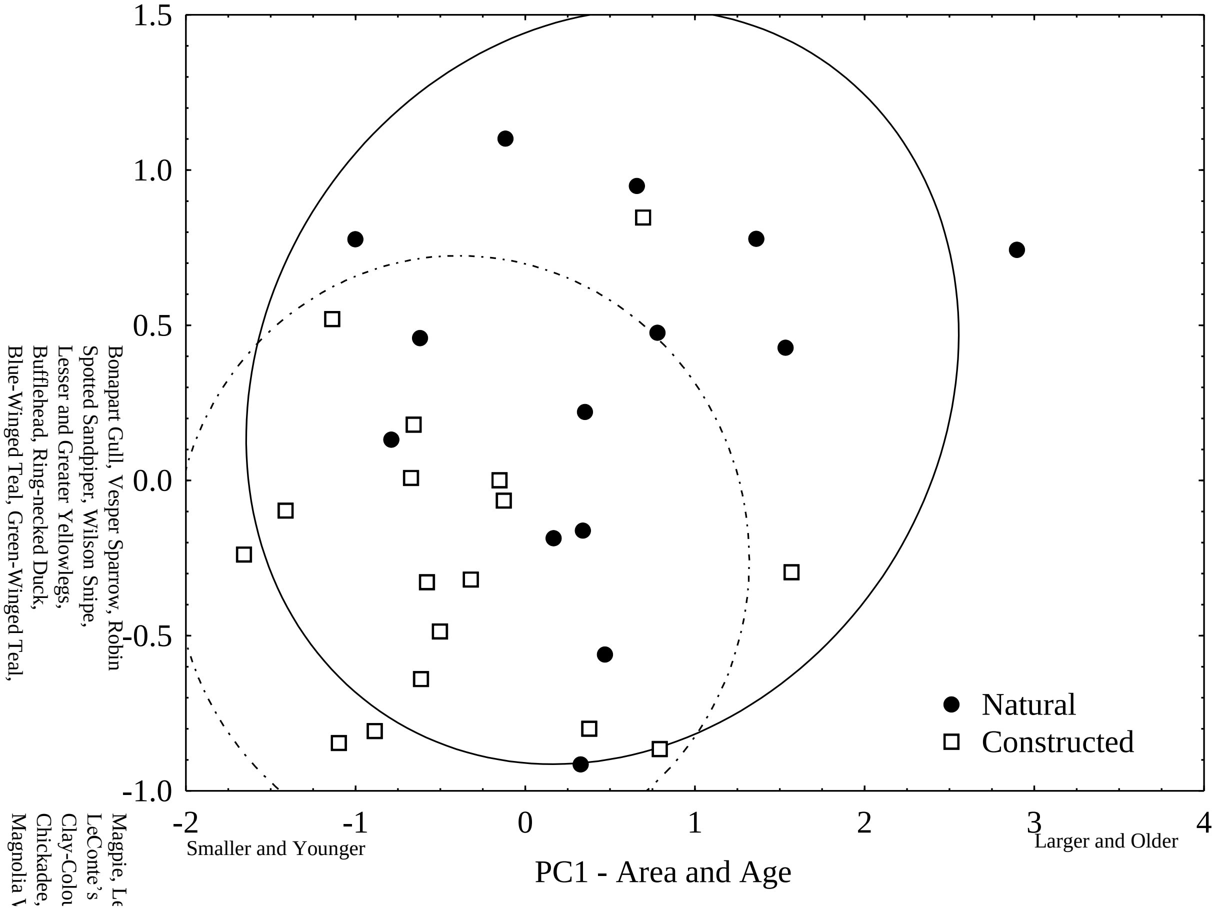

Figure 3.3. Relationship between NMD Axis 1 scores and values of PC-1 (area and age) at natural and constructed wetlands. Ellipses represent 70% confidence intervals.

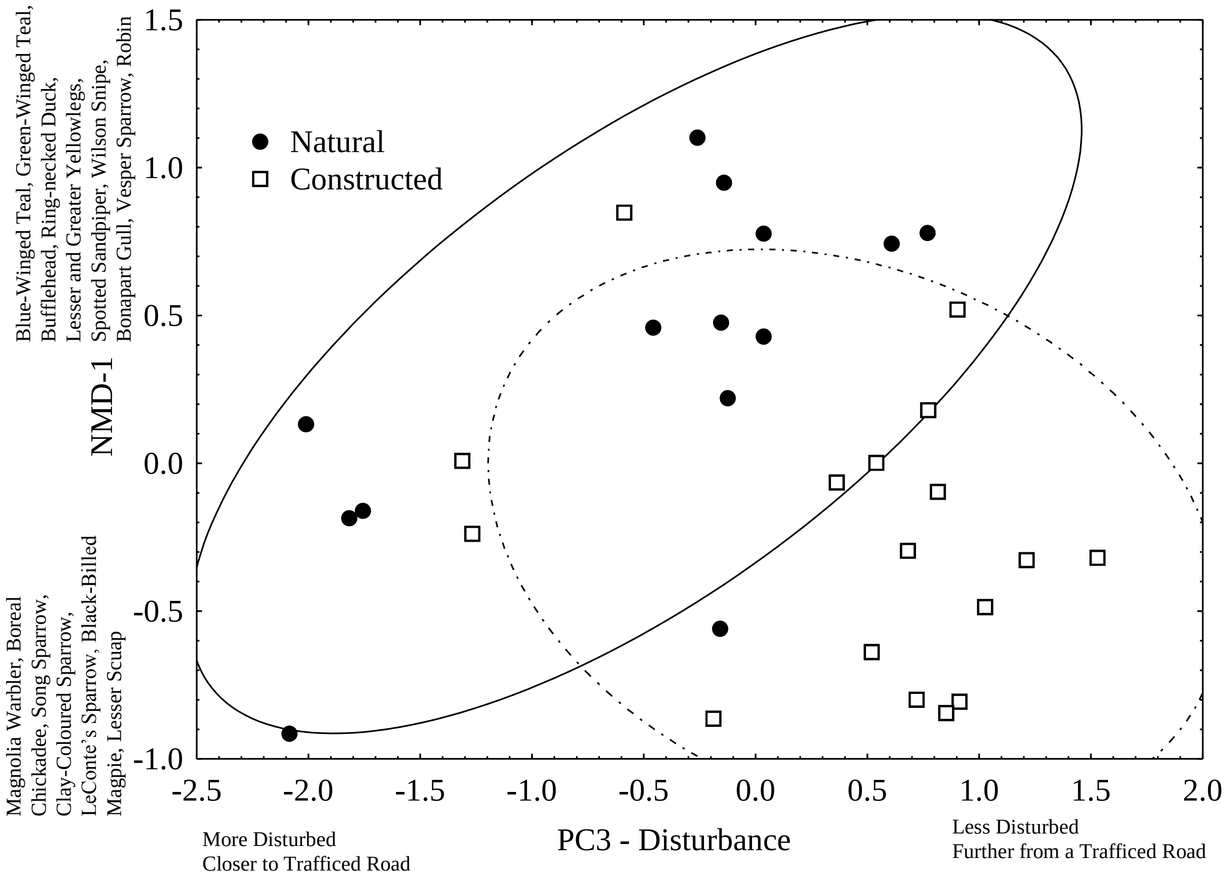

Figure 3.4. Relationship between NMD Axis 1 scores and values of PC-3 (measures of disturbance) at natural and constructed wetlands. Ellipses represent 70% confidence intervals.

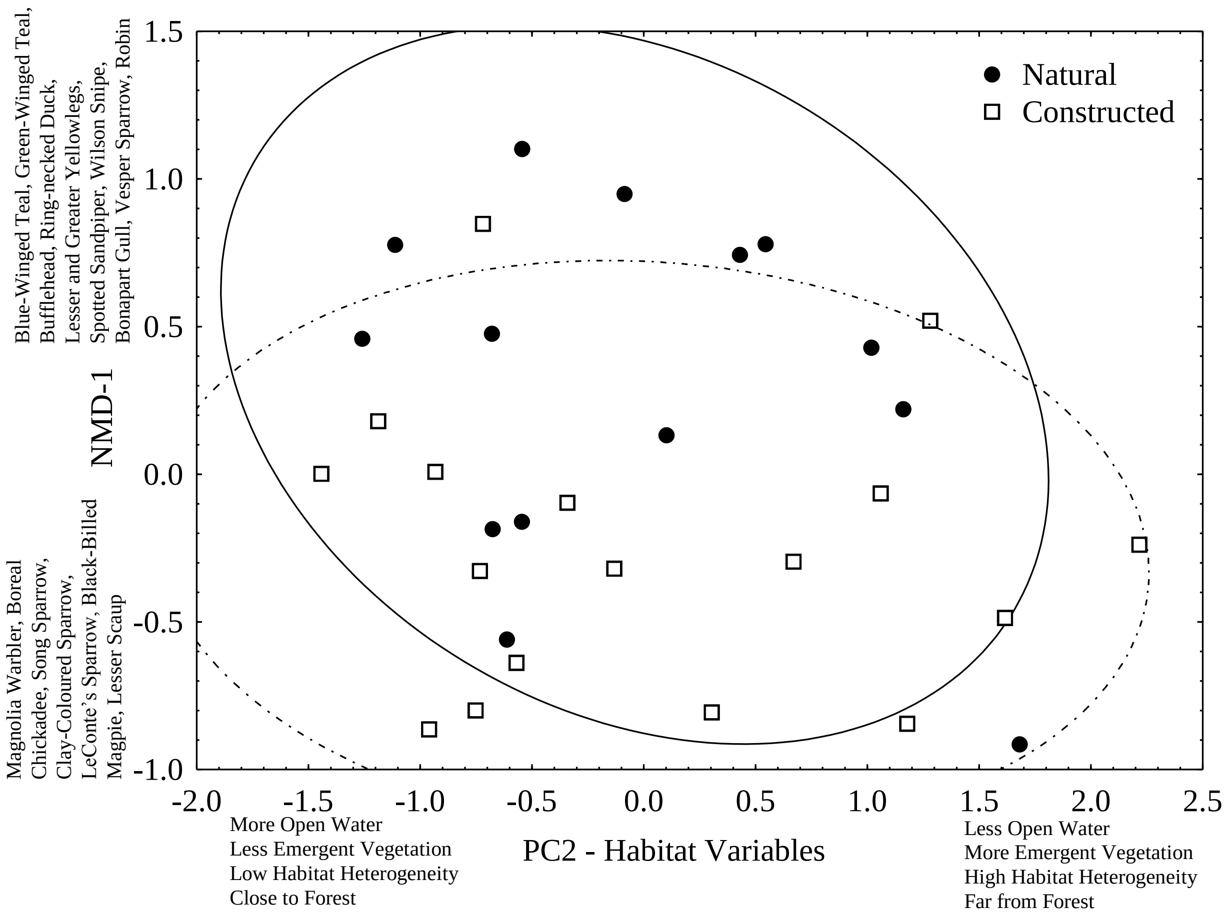

Figure 3.5. Relationship between NMD Axis 1 scores and values of PC-2 (habitat variables) at natural and constructed wetlands. Ellipses represent 70% confidence intervals.

(wetland birds) than constructed wetlands, which appear to support more NMD-1 negative species (forest and grassland birds). This difference may be due to differences in disturbance (PC-3) or it may be due to the relative cover of open water and emergent vegetation (PC-2) because as emergent vegetation increased, and cover of open water decreased, natural wetlands showed a moderate decrease from more NMD-1 positive species to more NMD-a negative species. Constructed wetland NMDS scores varied independently of PC-2 scores.

NMD-2 positive species tended to be those that are generalists whereas NMD-2 negative species were primarily terrestrial species. PC-1 (size), PC-3 (cover of open water) and PC-4 (distance to the nearest wetland) scores did not appear to be related to the species composition of NMD-2. Plots of NMD scores vs. PC-3 (disturbance) seemed to show that although constructed wetlands could have more NMD-2 negative species, those wetlands tended to be higher on the disturbance scale while natural wetlands that had more NMD-2 positive species tended to be lower on the disturbance scale (Figure 3.6). Constructed wetlands tended to have more NMD-2 positive species (generalists) while natural wetlands tended to have more NMD-2 negative species (terrestrial).

NMD-3 positive and negative species appeared to occur in both natural and constructed wetlands and thus provided no additional information regarding differences in natural and constructed wetland species composition.

Discussion

General Census Data

The general census data and a comparison of mean number of avian species observed at natural and constructed wetlands were discussed in detail in Chapter 2.

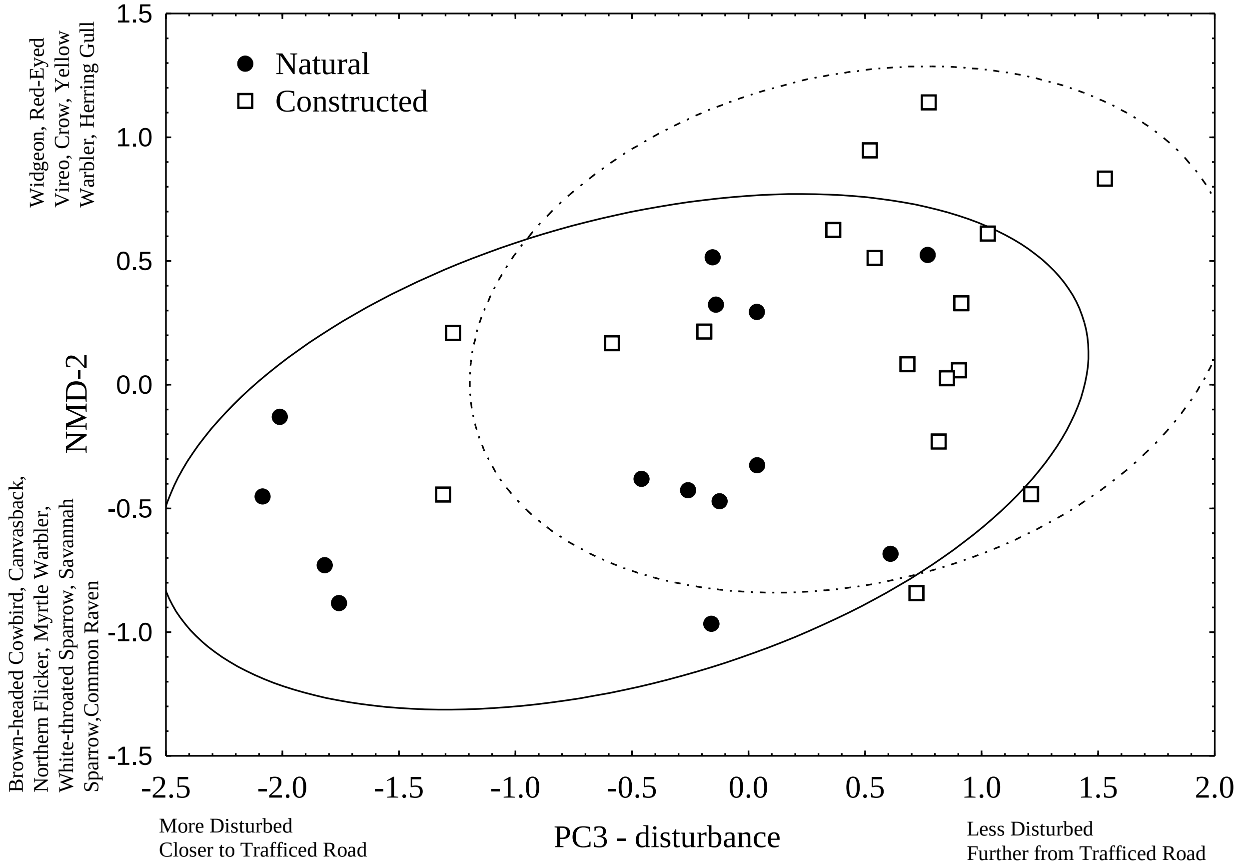

Figure 3.6. Relationship between NMD Axis 2 scores and values of PC-3 (measures of disturbance) at natural and constructed wetlands. Ellipses represent 70% confidence intervals.

Species-Area Relationships in Natural vs. Constructed Wetlands

In chapter 2 I reported a significant species-area relationship for natural wetlands but did not find a significant species-area relationship for constructed wetlands. However, my general postulate is that surveying avian communities in these wetlands over several years would be necessary to resolve whether the lack of a species-area relationship in the constructed wetlands was due to these wetlands being 1) too young and not having had sufficient time to reach equilibrium, 2) subject to a degree of disturbance whose effects override an area influence or 3) area *per se* is not the variable that controls species richness; instead other (perhaps covarying) variables, such as habitat attributes, better explain avian species richness in constructed wetlands. I address this last possible explanation in the next sections.

Habitat Heterogeneity-Richness Relationships in Natural and Constructed Wetlands

Avian species richness was independent of habitat heterogeneity in the natural wetlands but was positively correlated with heterogeneity of constructed wetlands. This partial inconsistency is surprising as many studies have documented the importance of both area and habitat heterogeneity to avian species richness, and the two are often correlated (Wiens 1989, Rosenzweig 1995) although the data appear to be independent in my data set. However, several studies have reported that area is the best predictor of species richness in wetland habitat islands (Howe 1984, Brown and Dinsmore 1986, Craig and Beal 1992, Craig 2008). It is possible that since the natural wetlands in this study are all relatively mature (greater than 30 years old), habitat heterogeneity might be sufficient to support the niche requirements of many different species and thus the size of the wetland become the limiting factor in species richness. Within the constructed wetlands species richness was significantly correlated with habitat heterogeneity under a one-tailed test; however richness was independent of area. Brose (2001) found that habitat heterogeneity explained more of the variability in avian species richness than either area or isolation in a suite of temporary wetlands in East Germany. Of particular interest is that habitat heterogeneity may be related to invertebrate richness (Hutchinson 1957, Chesson 2000, Amarasekare 2003) which is a source of food for many bird species. Therefore, habitat heterogeneity may affect avian species richness not just through increasing habitat variability, but also by increasing the amounts or variety of food sources. In contrast to the natural wetlands, constructed wetlands tended to be comparatively young. Thus, they may differ more in habitat heterogeneity and this may be the limiting resource for species richness. Overall, it would seem that no single variable can account for avian species richness across both classes of wetlands. Rather, even within a particular region and habitat type, different mechanisms seem to be at play in explaining species richness.

Habitat and Isolation Variables and the Species-Area Relationship

The variables that explained the greatest portion of the variability among natural wetlands were area (R^2=0.34), the distance of a wetland from the nearest disturbance (R^2=0.18), and the nearness of the nearest water body (R^2=0.08), although only distance to the nearest disturbance remained statistically significant in the final model. Together, these three measures of habitat explained 61% of the variation in species richness.

That area should be the strongest predictor of avian species richness supports the area *per se* theory, as has often been demonstrated (Howe 1984, Brown and Dinsmore 1986, Craig and Beal 1992, Craig 2008). For example, Murphy et al. (2004) found that 76% of avian species richness variability was explained by area alone. In the principal component analysis, age was correlated with the variables that measured size of the wetlands. This was likely because the largest wetlands also tended to be natural and therefore were older; so wetland age might also be important for species richness. Within restored prairie wetlands VanRees-Siewert and Dinsmore (1996) found no relationship between total wetland species richness and years since wetland restoration, while Hapner et al (2011) found that species richness increased in wetlands from 4 years since restoration to 10 years later. However, as our natural wetlands are all at least 30 years old, it is unlikely that age affected species richness in this group.

Within this study other habitat characteristics were also potential predictors of avian species richness. Natural wetlands that had higher species richness were also further from disturbances (such as trafficked roads or construction) and were further from the nearest water body. Findlay and Houlahan (1997) reported that avian species richness was lower in areas that had greater density of paved roads, suggesting that road noise or overall human activity may reduce habitat suitability for birds. The degree of isolation (distance from the nearest adjacent wetland) has been found to be negatively correlated with increasing species richness in other studies (Brown and Dinsmore 1986, Fairbairn and Dinsmore 2001, Paracuellos & Telleria 2004); i.e., wetlands more isolated from other wetlands have lower species richness, so it is odd that wetlands further from other water bodies had a higher species richness in this study. Alsfeld et al. (2011) also found that avian species decreased with proximity to additional wetland habitat but offer no explanation as to why. Within this study distance to the nearest wetland explained very little of avian species richness in natural wetlands (8%) and was non-significant. Further wetlands were often fairly near other wetlands (less than 500 m away) and the nearest body of water was often a wetland.

Additionally, Moller (1987) argued that isolation may not have an effect on taxa with large dispersal abilities. Perhaps the density of wetlands is so great in this region that isolation isn't important.

None of the variables that were measured explained a significant amount of the variation in species richness in constructed wetlands. At best, species richness was weakly negatively related to the relative amount of open water cover; a variable that correlated negatively with percent cover of emergent vegetation, habitat heterogeneity, and was loosely correlated with distance to the nearest forest. Some studies have found that areas with greater open water cover supports greater species richness (Craig and Beal 1992, Hapner et al. 2011). However, I did not find this trend in constructed wetlands. The proportion of emergent vegetation is complementary to the relative amount of open water in the study wetlands, which likely fosters greater species richness in the constructed study wetlands. Some other studies of avian species have reported finding a positive relationship between emergent vegetation and species richness (VanRees-Siewert and Dinsmore 1996, Fairbairn and Dinsmore 2001), whereas others have found a negative relationship (Hapner et al. 2011).

The lack of a significant relationship with distance from landscape disturbance in constructed wetlands may appear to counter the idea that disturbance affects species richness. However, if all of the constructed wetlands are subject to significant amounts of (perhaps diffuse) disturbance then it would mask any effects that one would be able to detect. In contrast, natural wetlands may experience a range of disturbance (reflecting their distribution in locations both inside and outside of mine lease areas) and thus permit one to observe differences in species richness with respect to area. Rooney and Bayley (2011) studied a similar suite of natural and constructed wetlands near Fort McMurray, AB, and found that aquatic plant diversity was lower in areas subject to disturbance (including mining, residential land cover and non-mining and gas development). This may translate into lower habitat heterogeneity which was significantly related to avian species richness in constructed wetlands in this study.

Few studies have examined factors affecting avian species richness in constructed wetlands. Alsfeld et al. (2010) studied how richness in constructed wetlands in Delaware varied with respect to several variables of distance-to-neighbouring-habitat and found that forest area and proximity to forest were the strongest predictors of avian species richness. However, Alsfeld et al. (2010) did not consider variables of wetland size or wetland habitat characteristics. Hapner et al. (2011) found that species richness was only loosely tied to distance to the nearest forest within created and restored wetlands of Wisconsin. Within the constructed wetlands of the oilsands leased sites, Dagenais' (2009) results corroborated those of Alsfeld et al. (2010), in that the overall species richness was greatest at wetlands closest to forest patches. In this study, the distance to the nearest forest was correlated weakly in the principal component analysis with percent open water and percent emergent vegetation cover. However, there was no significant relationship between species richness and percent open water cover in the constructed wetlands; so it would be difficult to comment on the relationship with proximity to forest. It is noteworthy that most wetlands were situated right at forest edge or within 50 m of a forest, still within the range of auditory detection of the point count. Therefore, some forest-resident bird species records were likely inadvertently included during the survey period and this may account for the lack of relationship.

Species Composition

Information on the species composition of the natural and constructed wetlands was analyzed to help elucidate what differences there were between natural and constructed wetlands. Natural and constructed wetlands do appear to differ in terms of their species composition, with natural wetlands having more water bird species (NMD-1 positive) and terrestrial species (NMD-2 negative) whereas constructed wetland communities were more likely to be composed of more woodland species (NMD-1 negative) and generalists species (NMD-2 positive). Avian species that were associated with NMD-3 appeared to be another grouping of water bird vs. woodland species. However, these species' occurrences did not vary between natural and constructed wetlands. Differences in species composition of natural and constructed wetlands have been shown in several studies (Snell-Rood and Cristol 2003, Alsfeld et al. 2010, Hapner et al. 2011, Begley et al. 2012). It is surprising that natural wetlands tended to have more wetland and water bird species whereas the constructed wetlands tended to have more woodland species. Natural wetlands tend to be older and more mature than the constructed wetlands, and Hapner et al (2011) found that in restored prairie pot-holes younger wetlands had more open water while older wetlands had more emergent vegetation; this translated into a successional replacement of water bird species (in younger wetlands) by old field species (in older wetlands). In a comparison of the natural and constructed prairie pot-hole wetlands Begley et al. (2012) found that the natural wetlands tended to have more woodland species than did the constructed wetlands. My results for NMD-1 seem to differ from these two studies. However, the natural wetlands did tend to be larger than the constructed wetlands and at a certain size the trade-off between emergent vegetation and open water may no longer matter as both classes of wetland may provide sufficient open water for water bird species. The exploratory analysis of NMD axis-1 vs. PC-

2 relative area of open water a appears to support this interpretation, as constructed wetlands appear to have no trend with cover of open water while natural wetlands that have less open water (and more emergent vegetation) tend to be dominated more strongly by tree and shrub nesting species (NMD-1 negative species).

NMD-1 also appeared to relate with disturbance. Overall, the constructed wetlands scored lower on the disturbance PC axis (i.e., were further from disturbance), and were consistently characterized by associated woodland species (NMD-1 negative). Interestingly, more disturbed natural wetlands were associated with woodland species while natural wetlands that were further from disturbance tended to be associated with more water bird species (NMD-1 positive). This may be because the distance to the nearest disturbance was often a road however I chose to include only trafficked roads as a disturbance. For natural wetlands the nearest road and disturbance was usually a high traffic one. Constructed wetlands were often equally close to a road (close to a disturbance) but those roads were rarely used (not trafficked) and this may be why constructed wetlands are further from disturbance. If we consider all roads, those experiencing high traffic and those with little traffic, then constructed wetlands overall would be close to a disturbance and have similar species composition as natural wetlands that are close to a disturbance (woodland species). In this case it could be said that proximity to road is related to woodland species while distance from a road is related to more water bird species. In this case it is likely not the traffic of the road that is causing the disturbance so much as being close to a cleared area of land.

Because NMD-2 species were related to disturbance, it is surprising that as both natural and constructed wetlands became less disturbed, species composition went from woodland species (NMD-2 negative) to generalist species (NMD-2 positive). However, if we consider again distance to the nearest road instead of disturbance to the nearest trafficked road, then in natural and constructed wetlands experiencing equal disturbance, constructed wetlands tend to have more generalist species while natural wetlands tend to have more woodland species. These results become more consistent with other studies that have assessed the role of disturbances on avian species richness (Findlay and Houlahan 1997, Forman and Alexander 1998, Alsfeld et al. 2010). In this study, roads were most often the nearest disturbance. In a study of wetland bird communities in agricultural and urban landscapes proximity to roads altered avian assemblages (Whited et al. 2000), although the authors did not clarify in what way.

Two studies that examined avian composition in natural and constructed wetlands (Alsfeld et al. 2010, Begley et al. 2012) found that species composition of wetlands was most strongly related to proximity to forest habitat. Additionally, within the constructed wetlands of Fort McMurray, AB, Dagenais (2009) observed that constructed wetlands closest to forest patches tended to have greater species richness. This principal component (PC-2) appears to explain differences in species composition in natural but not in constructed wetlands such that being closer to forest habitat may be loosely related to having more woodland species. However in this study most wetlands were right at the edge of a forest so it is unlikely that there would be a relationship. Based on previous research, proximity to forest patch is likely an important determinant of species richness and community composition and future studies should attempt to examine this by surveying wetlands that have greater variation in their proximity to forest habitat.

Summary and Recommendations

I found qualified evidence that wetlands may be considered habitat islands and that species-area relationships occur among natural boreal forest wetlands in the study area. Therefore, the construction and conservation of larger wetlands would maximize avian species richness within this region.

I also found that constructed wetlands may support similar numbers of species to natural wetlands overall, but constructed wetlands differ from natural wetlands in that species richness appears to be independent of area and of other specific habitat variables that were measured in this study. However, constructed wetlands that were more heterogeneous tended to support more species than wetlands of the same size that were dominated by single habitat types. Species richness of natural wetlands was most strongly related to wetland area, and proximity to disturbance was associated with lower avian species richness. Similarly, disturbance (typically any road type) was greater at or near constructed wetlands than in the natural wetlands and this was reflected in differences in the community composition of the wetlands, with constructed wetlands tending to have species that are generalists. A greater occurrence of generalist species in the smallest constructed wetlands may account for the lack of area-related difference in species richness in constructed wetlands that other studies have reported (e.g. Hapner et al. 2011). Clearly, disturbance, often roads, and human activity can have strong effects on avian ecology and efforts that minimize disturbance experienced at both natural and constructed wetlands should support richer avian communities.

Despite the fact that avian species richness was comparable between natural and constructed wetlands, community composition was not. In my study disturbance appeared to explain differences in composition. Additionally, several other studies of restored and constructed wetlands have cited proximity to forest as important for diversifying wetland species composition, and this should be addressed in future constructed wetland research. Surveys of the avian species in these wetlands should be performed over several years to assess both interannual variation and possible succession-associated changes in the avian community. Finally, given that that variables other than area alone may influence wetland species richness in a wetland, such factors should be included as covariates when developing strategies to conserve and restore wetlands.

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CHAPTER IV

GENERAL DISCUSSION

Overview

The aim of this study was to study avian species-area relationships in natural boreal forest wetlands of northeastern Alberta and compare the patterns to those observed in wetlands constructed by oil sand industry partners in the postmining- landscape after open pit oil sands extraction. Further, I wanted to test if wetland area better predicted the species richness of species at high trophic levels in the food web (birds) than producer autotrophic species (plants), as predicted trophic island biogeography theory. I then wanted to determine the extent to which other habitat characteristics may account for avian species richness in wetlands. Finally, I assessed whether natural and constructed wetlands differed in avian species composition and what habitat characteristics may account for these differences.

My findings were as follows:

1) There was no difference in the mean avian species richness of natural and constructed wetlands. Avian species richness was a function of area in natural wetlands, whereas there was no significant relationship between species richness and area of constructed wetlands.
2) There was significantly greater plant species richness in natural wetlands than in constructed wetlands. Plant richness was independent of area of both natural and constructed wetlands.
3) Across all wetlands and both wetland classes, plant species richness was greater than avian species richness. This difference was more pronounced in natural wetlands than in constructed wetlands.

4) In natural wetlands the avian species-area relationship was stronger than that of the plant species-area relationship, suggesting avian species richness is more related to area than that of plants and providing support for the trophic theory of island biogeography.
5) In constructed wetlands the strength of the species-area relationships of plants and birds were the same; thus no support for trophic island biogeography.
6) Avian species richness was unrelated to habitat heterogeneity in natural wetlands but in constructed wetlands avian species richness was significantly positively correlated with habitat heterogeneity.
7) The avian richness-area relationship in natural wetlands was strengthened by accounting for distance to the nearest physical disturbance; wetlands further from disturbance had more species than wetlands of equivalent area that were situated nearer to a disturbance. Area explained the greatest portion of the variability. The nearness of an adjacent wetland (a measure of isolation) decreased species richness but was non-significant and explained little of the variability in richness.
8) No variable in the multiple regression explained a significant amount of the variability of avian species-richness in constructed wetlands. A negative relationship with the percent cover of open water (correlated in the principal component with positive values of habitat heterogeneity, percent cover of emergent vegetation and marginally with distance to nearest forest) explained the largest portion but was non-significant.
9) Natural and constructed wetlands differed in species composition significantly with respect to two species groupings. Natural wetlands appeared to contain more water

bird species and terrestrial species whereas constructed wetlands contained more woodland species and generalist species. These species composition differences appear to be related to differences in the relative amounts of open water and emergent vegetation, overall area of the wetland and distance to the nearest disturbance between natural and constructed wetlands.

Trends in Avian Species Richness and Recommendations

A significant species-area relationship in birds was observed for natural wetlands in the study area, and this adds further support to the ubiquity of avian species-area relationships. However, observed z-value (slope of the relationship) of 0.1 is rather low compared to the z-values in other ecological islands, which tend to be in the range of 0.17-0.72 (Watling and Donnelly 2006), although Smith and Chow-Fraser (2010) observed an avian species-area relationship with a z-value of 0.076 within Great Lakes coastal wetlands. It has been suggested that the range of the habitat sizes (‘island areas’) included in the study may influence the z-value, with small ranges inflating it (Martin 1981). Smith and Chow-Fraser (2010) demonstrated this by observing that excluding the larger wetlands from their analysis resulted in a larger z-value. The wetland selected for this study were designed to encompass a large range in sizes (0.15 ha -150 ha) and this may explain the relatively low z-value observed in this study. It is possible that my low z-score may be the result of not increasing survey effort at the larger wetlands. Within the small wetlands, three survey points allowed for a survey of the entire wetland. At the larger wetlands I was not able to survey the entire landscape and this may have resulted in missing some species in these wetlands, thus under representing species richness at the larger wetlands and lowering the z-score. It also has been suggested that z-values have no actual biological significance and are simply the result of deriving logspecies/logarea relationships (Connor and McCoy 1979).

The trophic theory of island biogeography predicts that the z-value, or the strength of the species-area relationship, is meant to increase as a function of a guild's trophic position (Holt et al. 1999); species higher in the food web increase in richness faster as area increases than those lower. This is argued to be because the higher trophic level species require larger areas to provide sufficient food as well as being less abundant and thus more likely to go extinct. This trend was found in natural wetlands but not in constructed, largely because area was not related to species richness for plants or birds in constructed wetlands. Therefore this study provides support for the existence of differences in strength of the species area-relationship based on trophic position however support could be strengthened with inclusion of data from the invertebrate species because they are consumers of plant species as well as prey for avian species. Further, because avian species occupy a variety of positions in the food web, examining the species-area relationship by avian guild may also be important in studying trophic effects.

In this study we observed that larger natural wetlands tended to support more avian species than smaller wetlands, in accordance with the findings of most studies that have examined relationships of area and species richness. Other research also suggests that larger wetlands tend to support more rare species (uncommon or at risk; Craig 1990, Craig and Beal 1992, Craig 2008) as well as being able to sustain populations that are larger and thus less likely to go extinct as well as those species that have minimum area requirements for colonization (Brown and Dinsmore 1986, Naugle et al. 1999, Riffell et al. 2001). While it is tempting to say that larger wetlands are 'better', Craig (2008) suggested that a single large island may be subject to factors that are detrimental to species richness such as isolation from other habitats. Although the avian species-area relationship of constructed wetlands was not significantly different from that of natural wetlands, the relationship was so variable that it was not significantly different from zero, either. It would appear that avian species richness is independent of area in these wetlands, thus the area *per se* hypothesis does not apply to the constructed wetlands. The absence of a significant species-area relationship appears to be due to the extreme variability of species richness in constructed wetlands of similar sizes and could be attributed to three possible causes. Firstly, the wetlands may not be mature enough, and thus have not reached equilibrium between immigration and extinction. Second, the constructed wetlands may be subject to so much disturbance due to their location that a stable community cannot form. Third, it may be that area does not explain species-richness and so, other variables, such as habitat are more important. All of these causes could potentially explain the scatter in species richness of constructed wetlands of similar size. Continuing to monitor these wetlands over several years should help elucidate the mechanisms behind constructed wetland avian species richness because it would allow for equilibrium to settle between immigration and extinction. If species-area relationships do not occur over time this may indicate disturbance is disrupting equilibrium from forming or that area is not important for species richness within these wetlands.

Not all predictions of island biogeography theory were confirmed in the natural wetlands because while species richness was related to area, isolation from other wetland habitat did not affect species richness. Several studies of wetland islands have found support for proximity to additional wetland habitat increases species richness (Brown and Dinsmore 1986, Fairbairn and Dinsmore 2001, Paracuellos & Telleria 2004). The absence of this relationship may be because these wetlands were, overall, fairly well connected to each other and often existed within a matrix of other water bodies. Alternatively, in a review of 81 studies that included isolation in their analysis, 54 (67%) demonstrated no relationship of isolation to area (Watling and Donnelly 2006). However, we cannot exclude isolation entirely from analysis. Habitat fragmentation and isolation are often correlated; as a habitat becomes smaller it also becomes more distant from neighbouring habitat (Watling and Donnelly 2006) and in this way, small habitats may be crucial in maintaining connectedness (Baum et al. 2004). Further, isolation may influence plant composition and thus habitat (Connor and McCoy 1979) so isolation may not influence species richness directly but may act on richness by altering habitat heterogeneity.

Habitat heterogeneity hypothesis did not seem to come into play in the natural wetlands as avian species richness was not related, however this may be because the natural wetlands already have sufficient habitat and thus area becomes the limiting factor in species colonization and persistence. Increasing habitat heterogeneity did correlate with moderate significance with avian species richness in the constructed wetlands thus it would appear that while area is the most important factor for species richness in natural wetlands, habitat heterogeneity explains the most in the constructed wetlands.

There is a tendency for ornithologists to focus on only area or on habitat type when looking for trends in species richness. However, avian wetland species richness has been demonstrated to be predicted by both wetland size (Benassi et al 2007) and by other habitat characteristics (Elphick and Oring 1998). In this study I demonstrated that different habitat characteristics can improve our predictive power of avian species richness and that important factors may be different for different wetlands, even within the same region (within this study area and disturbance for natural wetlands and a moderate trend with habitat heterogeneity for constructed). Considering only one of these variables would likely result in conservation or construction of wetlands that are not able to support strong and diverse avian communities. Large wetlands may have sufficient area to support many species but if the necessary habitat and food sources are not in place, many birds will not be able to colonize. Further, habitat heterogeneity may provide habitat and food for many different specialist species but without a large enough area, species will be limited by space and show low abundance and higher extinction.

In addition to considering the influence of local factors on species richness (area and habitat), landscape level effects, such as the spatial arrangement of wetlands, may be important in species richness (Guadagnin et al 2009). In a review of 118 studies, Watling and Donnelly (2006) discovered that in one-fifth of the studies, area and isolation were intercorrelated such that an increase in habitat loss would also result in an increase in the distance separating neighboring fragments (Andren 1996). Birds are mobile and may require multiple sites to support their resource requirements (Guadagnin and Maltchik 2007). Thus, the reduced size and the increased isolation of habitat may have a synergistic negative effect on species richness. When developing reclamation landscapes, industry partners should take into consideration the importance of connectedness. By allowing species to move between wetland patches, the connectivity and structural matrix of a landscape of habitat patches may increase or reduce the risk of extinction (Gonzales et al. 1998, Ricketts 2001). The best reclamation strategy will likely incorporate a few large wetlands within a network of smaller wetlands.

Finally, it is important to remember that while area, isolation and habitat may be the driving forces of what determines species richness on habitat islands, other factors (such as disturbance in this study) may have mitigating effects on species richness. Thus examining all forces acting on avian species richness is crucial for conserving and constructing wetlands.

Natural and constructed wetlands did not different significantly in the mean avian species richness though the mean species richness in plants did differ between the wetland classes. However, species composition may still differ as the constructed wetlands may have more invasive species (Suding et al. 2004) or may show different succession of species. Hapner et al. (2011) studied restored wetlands over a 10-year period and found that the species composition changed from primarily waterbird-dependent and wetland species to old field species. I also observed some differences in the species composition of the natural and constructed wetlands. The natural wetlands tended to have more aquatic species on axis-1 and an assortment of terrestrial species on axis-2 while the constructed wetlands contained more woodland species on axis-1 and generalist species on axis-2. The species composition of these wetlands appeared to be related to the amount of disturbance as well as the relative amounts of open water and emergent vegetation in the wetlands. It is unsurprising that species composition was different between the two wetland classes even though species richness was comparable because different species have different habitat requirements. A wetland requires sufficient open water for waterbirds as well as mud regions for shorebirds, and emergent vegetation for the marsh nesting species in order to contain the full suite of wetland-related bird species. Wetland-related species may require grassland, shrubby habitat or forested regions. This range of habitats tended to be present in natural wetlands. The positive relationship observed between species richness and habitat heterogeneity in constructed wetlands likely reflects the absence of sufficient relative quantities of one or more of these habitat types in non-natural wetlands. Similarly, Delphey and Dinsmore (1993) found that wet meadow and low prairie regions were absent from the restored prairie wetlands in their study and this translated into reduced numbers of several wet meadow/low prairie species.

My findings suggest that a rich avian species community could best be sustained through the construction and conservation of larger wetlands. Additionally, because I have found support for trophic level affecting the species-area relationship, larger wetlands may be needed to draw the high level consumers. Indeed, birds of prey were detected primarily at the largest wetlands or within a large grouping of smaller wetlands. However it is likely that a few large wetlands within a matrix of connected wetlands may be the best strategy to prevent the potentially negative effects of isolation. This would require reclamation strategies move towards restoring an entire wetland landscape rather than individual wetlands. Additionally, some planting may improve the habitat heterogeneity of the wetland, especially of plant species that may have lower dispersal abilities. This may be especially important for avian species richness of constructed wetlands as species richness had a positive relationship with habitat heterogeneity. Further, wetland construction should include the full range of wetland habitats (wet meadow, prairie, etc.) to promote diverse avian colonization. It is clear from this study that anthropogenic disturbance (especially roads) can reduce the quality of a habitat for avian species, translating to a decrease in species richness as well as differences in community composition. Therefore, I also recommend that wetlands be constructed in areas that are as isolated from disturbance as possible. Finally, in order to increase species richness and provide suitable habitat for the entire range of wetland and wetland related species, wetland construction should move toward constructing wetlands with all different habitat zones including open water, emergent vegetation, muddy shore, grassland, shrubs and proximity to forest habitat.

Limitations and Recommendations for Future Work

Although surveys were conducted during two consecutive years, avian species counts for one summer were considered to be unreliable due to the effects of nearby forest fires, flooding and a late start in the 2011 field season. Thus, our results may only be representative of the 2012 breeding birds in the region. Dagenais (2009) found considerable variation between the two years of her study of constructed wetlands of the oil sands region (reference and oil sands process material wetlands) for both breeding and total avian species richness. Therefore, species richness is likely variable between years in the region. Further, important variables controlling species richness, such as open water area, may vary seasonally. For example, Paracuellos and Telleria (2004) surveyed the dabbling and diving ducks of wetlands in Spain and found that isolation was an important predictor of species richness in the winter whereas emergent vegetation was a more important factor in the spring and summer. It is possible that other habitat factors may be important for avian species richness in the winter months and this may have application in wetland construction for overwintering birds. Further, factors that are important in one region may not be effective in predicting species richness in another region (Johnson and Igl 2001); I found this to be true in comparing the natural and constructed wetlands. Thus it is important to survey habitats at different times of year and to not apply trends from one region or habitat to another without first assessing it.

I used the point count method of surveying avian species richness which is a well-supported method of surveying bird species (Bibby 2000) and is used in the Marsh Monitoring Program and the Breeding Bird survey as well as many species-area relationship studies. This method permits one to quickly estimate the number of bird species in a habitat by sight or sound. Unfortunately, species that are secretive or seldom vocalize can often be missed. Thus, it is possible I did not detect all avian species in the region. However, because we used the same survey method across all wetlands, secretive species would be consistently missed, and thus the species-area relationship should not be affected.

Finally, this research was performed on wetlands that are marsh-like, with areas of open water that are flooded the majority of the year. Oilsands companies have emphasized constructing marsh-like wetlands in the past because they have been the most suitable means of assessing questions of aquatic toxicity. However, fen-like systems constitute the major wetland type within the region (Purdy et al., 2005). The oil sands companies recognize this, and have recently built two full-sized demonstration fens (Sandhill Fen (Vitt and Bhatti 2012) being developed by Syncrude Canada, Ltd. and Nikanotee Fen (Price et al. 2010) constructed by Suncor Energy Inc.). Thus, this research should incorporate assessment of boreal fens in the Fort McMurray area to determine the habitat characteristics most important in sustaining fen species richness, as well as to eventually providing the capacity to compare constructed fens to naturally occurring fen habitat.

Significance

This research is the first to investigation to actively examine differences in trophic level on species richness in boreal forest wetlands as well as in constructed wetlands. This is also the first comparison of the avian species area relationships of natural vs. constructed wetlands that also assesses habitat characteristics related to species richness and species composition. I have provided further evidence for species-area relationships, the existence of trophic level differences on the species-area relationship and that area, habitat heterogeneity and other habitat characteristics can all affect bird species richness and composition in wetlands of the study region. Consequently a more integrated approach to examining species richness is warranted in future studies.

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APPENDIX I - WETLAND LOCATIONS, AGE AND CLASS

Formal wetland names are those summarized by Golder (2002), and/or current documents and maps of Suncor Energy, Inc., Syncrude Canada, Ltd. and CEMA. Alternate wetland names are synonyms in former or current use by oilsands operators or researchers.

Formal Wetland Name	Alternate Name	Location Information	Northing	Easting	Age	Constructed=1 or Natural=0	OSPM=1 or Reference=0
Demo		12V	458219	6326803	20	1	1
Golden Pond		12V	462066	6317226	12	1	0
Bill's Pond		12V	462816	6317428	15	1	0
Peat Pond		12V	462075	6316867	12	1	0
Seepage Control		12V	461313	6328720	34	1	
Shallow Wetland		12V	458149	6326667	20	1	0
4-m CT		12V	467670	6316509	18	1	1
Sand Pit	Crescent	12V	475267	6306475	7	1	0
Suncor Duck Pond		12V	467202	6316106	16	1	0
Jan's Pond		12V	467697	6316631	12	1	1
Suncor Sustainability Ponds	MFT North and South	12V	467517	6316575	19	1	1
Natural Wetland		12V	468962	6315305	27	1	1
Weir 1	Loon Lake	12V	471694	6314892	41	1	
Shipyard Lake		12V	473503	6314742	50	0	0
Floodplain		12V	472877	6315493	41	1	0
1-m CT		12V	467704	6316357	12	1	1
Crane Lake		12V	466383	6317047	40	1	0
High Sulphate	Crane L. Duck Pond	12V	466387	6317226	27	1	0
Muskeg		12V	463354	6332735	34	0	0
Tower Road 1	N1 Wetland	12V	469719	6289166	50	0	0
none	N20 Moose	12V	469444	6289133	50	0	0
Tower Road 2	Jule's Wetland	12V	464432	6290827	50	0	0

Tower Rd Spruce Pond	Hammer-Stake Beaver	12V	463700	6290570	50	0	0
none	Red Jacket	12V	459752	6311074	50	0	0
Bridge Wetland	Sheeva's Wetland	12V	463442	6332817	50	0	0
none	Rhino's	12V	479439	6274247	50	0	0
none	Blueberry Wetland	12V	482816	6263899	32	0	0
none	Mosquito Wetland	12V	483152	6263740	50	0	0
none	Beaver Lodge	12V	483320	6263414	50	0	0
none	Table Wetland	12V	483524	6263500	32	0	0
none	Hidden Wetland	12V	6290824	464426	50	0	0

APPENDIX II: AVIAN POINT COUNT DATA

Wetland Name	Point Count Date	Temperature (^oC)	Beaufort Wind Scale (0-6)	Background Noise (0-4)	Cloud Cover (0-10)	Avian Spp	Plant Spp
Demo	31-May-12	16	2	1	0	14	27
Golden Pond	31-May-12	13	4	3	1	13	20
Bill's Pond	31-May-12	13	3	3	0	12	22
Peat Pond	31-May-12	12	4	3	2	9	23
Seepage Control	31-May-12	14	3	2	0	19	19
Shallow Wetland	31-May-12	14	3	1	0	17	30
4-m CT	17-May-12	8	1	2	10	12	no data
Sand Pit	18-May-12	7	0	3	8	15	17
Duck Pond	17-May-12	10	2	2	8	17	23
Jan's Pond	17-May-12	8	1	3	8	16	13
Sustainability	08-Jun-12	12	1	1	0	9	16
Natural Wetland	18-May-12	4	0	2	10	17	17
Weir 1	18-May-12	4	1	2	10	12	16
Shipyard Lake	18-May-12	6	1	2	10	20	27
Floodplain	28-May-12	8	0	0	2	13	8
1-m CT	08-Jun-12	12	0	1	0	15	17
Crane Lake	16-May-12	9	0	2	0	22	19
High Sulphate	16-May-12	8	1	2	1	11	12
Muskeg	17-May-12	8	1	4	10	15	36
Tower Rd 1/N1	16-May-12	5	1	2	1	11	33
N20 Moose	16-May-12	5	1	2	1	13	38
Tower Rd 2/Jule’s	28-May-12	8	0	3	1	20	25
Tower Rd Spruce	16-May-12	5	1	1	1	8	33
Red Jacket	18-May-12	-2	1	1	1	16	31
Bridge/Sheeva's	17-May-12	8	1	3	10	13	28
Rhino's	21-May-12	7	1	1	10	18	24
Blueberry Wetland	21-May-12	7	1	2	10	11	38

Mosquito Wetland	21-May-12	7	1	2	10	8	no data
Beaver Lodge	21-May-12	7	2	2	10	19	28
Table Wetland	21-May-12	7	1	2	10	9	27
Hidden Wetland	16-May-12	5	1	1	1	12	no data

APPENDIX III: WETLAND AREA AND DISTANCE MEASURES

Wetland Name	Area Open Water (ha)	Perimeter Emergent (m)	Area Total Wetland (ha)	Area of Emergent Veg (ha)	Nearest Forest (m)	Nearest Wetland (m)	Nearest Waterbody (m)	Nearest Disturbance (m)	Nearest Road (m)
Demo	2.46	592.16	2.46	0.00	38.94	48.03	48.03	475.70	475.70
Golden Pond	0.6	465.56	0.60	0.00	0.00	323.10	93.05	93.05	78.86
Bill's Pond	0.19	315.00	0.58	0.39	0.00	183.34	183.34	410.70	429.87
Peat Pond	0.75	394.42	0.75	0.00	0.00	323.10	385.34	385.24	38.53
Seepage Control	1.48	761.00	2.42	0.94	33.92	140.26	140.26	92.00	92.00
Shallow Wetland	0.25	764.00	2.75	2.50	45.07	48.03	48.03	189.00	189.00
4-m CT	0.07	382.00	0.51	0.44	0.00	22.49	163.97	163.97	400.64
Sand Pit	0.34	500.00	0.51	0.17	135.48	398.18	532.09	0.00	0.00
Duck Pond	0.67	473.00	0.67	0.00	0.00	247.17	247.17	0.00	0.00
Jan's Pond	0.26	276.20	0.37	0.11	0.00	22.49	112.85	112.85	389.82
Sustainability	1.07	638.05	1.07	0.00	27.62	79.24	79.24	232.38	232.38
Natural	0.72	620.90	1.16	0.44	0.00	1800.41	288.68	288.68	65.83
Weir 1/Loon	5.62	1140.00	5.62	0.00	0.00	323.03	343.34	44.12	0.00
Shipyard L.	25.32	6938.00	151.00	125.68	0.00	737.24	163.18	96.45	96.45
Floodplain	3.3	862.00	3.30	0.00	0.00	737.24	15.08	765.94	0.00
1-m CT	0.4	242.00	0.40	0.00	0.00	58.26	91.19	91.19	470.66
Crane Lake	18.51	1916.82	22.60	4.09	0.00	148.95	148.95	248.00	248.00
High Sulphate	1.3	256.00	4.00	38.70	0.00	148.95	186.63	186.63	292.86
Muskeg	0.98	816.00	3.22	2.24	0.00	142.93	50.51	72.86	72.86
Tower Rd 1/N1	0.53	887.00	2.11	1.58	0.00	158.37	158.37	0.00	0.00
N20 Moose	0.58	987.50	3.39	2.81	0.00	158.37	158.37	0.00	0.00
Tower Rd 2/Jule's	5.08	2947.00	12.70	7.62	0.00	70.70	70.70	213.80	213.80

Tower Rd Spruce	0.55	347.00	7.80	7.25	0.00	115.12	115.12	0.00	0.00
Red Jacket	0.43	620.00	0.93	0.50	0.00	104.86	104.86	63.33	63.33
Bridge/Sheeva's	0.71	4364.00	40.00	39.29	0.00	142.93	61.95	54.38	54.38
Rhino's	1.44	1729.31	5.21	3.77	0.00	396.06	396.06	35.69	35.69
Blueberry	0.22	333.24	0.44	0.22	0.00	90.47	90.47	0.00	0.00
Mosquito	0.26	212.96	0.26	0.00	0.00	97.44	97.44	20.95	20.95
Beaver Lodge	1.24	1385.65	5.08	3.84	0.00	67.06	67.06	37.34	37.34
Table Wetland	0.15	165.00	0.15	0.00	0.00	12.36	12.36	42.10	42.10
Hidden Wetland	1.15	678.56	5.00	3.85	0.00	90.96	90.96	34.32	34.32

APPENDIX IV: PERCENT COVER OF MAJOR WETLAND HABITAT

Wetland Name	PctEmergentVeg	PctOpenWater	PctMudSandRock	PctTreed	PctShrub
Demo	20	80	0	0	0
Golden Pond	20	80	0	0	0
Bill's Pond	40	60	0	0	0
Peat Pond	10	90	0	0	0
Seepage	40	50	0	10	0
Shallow Wetland	70	30	0	0	0
4-m CT	80	20	0	0	0
Sand Pit	40	15	0	45	0
Duck Pond	10	90	0	0	0
Jan's Pond	20	80	0	0	0
Sustainability	10	90	0	0	0
Natural Wetland	10	90	0	0	0
Weir 1	20	80	0	0	0
Shipyard Lake	40	50	0	10	0
Floodplain	0	70	30	0	0
1-m CT	70	30	0	0	0
Crane Lake	10	0	0	60	30
High Sulphate	10	80	0	10	0
Muskeg	40	30	3	20	7
Tower Rd 1/N1	2	80	0	10	8
N20 Moose	10	80	5	5	0
Tower Rd 2/Jule's	50	50	0	0	0
Tower Rd Spruce	45	5	0	30	20
Red Jacket	1	69	0	30	0
Bridge/Sheeva's	60	36	0	4	0
Rhino's	20	80	0	0	0

Blueberry Wetland	0	50	0	50	0
Mosquito Wetland	10	90	0	0	0
Beaver Lodge	30	70	0	0	0
Table Wetland	10	90	0	0	0
Hidden Wetland	20	80	0	0	0

APPENDIX V: AVIAN SPECIES DETECTED AT THE NATURAL AND CONSTRUCTED WETLANDS

Wetlands are organized by size from smallest to largest. Avian species are listed alphabetically by common name.

		Wetland Name:	Table Wetland	Mosquito Wetland	Jan's Pond
		Wetland Type:	n	n	y
		Wetland Area (ha)	0.15	0.26	0.37
Common Name	**Scientific Name**	**Acronym**			
American Coot	*Fulica americana*	AMCO			
American Crow	*Corvus brachyrhynchos*	AMCR	x		x
American Kestrel	*Falco sparverius*	AMKE			
American Redstart	*Setophaga ruticilla*	AMRE			
American Robin	*Turdus migratorius*	AMRO	x	x	x
American Widgeon	*Anas americana*	AMWI			
Bald Eagle	*Haliaeetus leucocephalus*	BAEA			
Barn Swallow	*Hirundo rustica*	BASW			
Belted Kingfisher	*Megaceryle alcyon*	BEKI	x	x	
Black and White Warbler	*Mniotilta varia*	BAWW			
Black-billed Magpie	*Pica hudsonia*	BBMA			x
Blackpoll Warbler	*Setophaga striata*	BPWA			
Blue-headed Vireo	*Vireo solitarius*	BHVI			
Blue-winged Teal	*Anas discors*	BWTE			
Bonaparte's Gull	*Chroicocephalus philadelphia*	BOGU	x		
Boreal Chickadee	*Poecile hudsonicus*	BOCH			
Brown-headed Cowbird	*Molothrus ater*	BHCO			
Bufflehead	*Bucephala albeola*	BUFF	x	x	
Canada Goose	*Branta canadensis*	CAGO			
Canvasback	*Aythya valisineria*	CANV			x
Chipping Sparrow	*Spizella passerina*	CHSP	x		x
Clay-coloured Sparrow	*Spizella pallida*	CCSP			
common Golden Eye	*Bucephala clangula*	COGO			
Common Grackle	*Quiscalus quiscula*	COGR			
Common Loon	*Gavia immer*	COLO			
Common Raven	*Corvus corax*	CORA			x
Common Yellowthroat	*Geothlypis trichas*	COYE		x	

Gadwall	*Anas strepera*	GALD			
Gray Jay	*Perisoreus canadensis*	GRJA			
Greater Yellowlegs	*Tringa melanoleuca*	GRYE			
Green-Winged Teal	*Anas carolinensis*	GWTE			
Hermit Thrush	*Catharus guttatus*	HETH			
Herring Gull	*Larus argentatus*	HEGU			
Horned Grebe	*Podiceps auritus*	HOGR			
Killdeer	*Charadrius vociferus*	KILL			
Least Flycatcher	*Empidonax minimus*	LEFL			
LeConte's Sparrow	*Ammodramus leconteii*	LCSP			
Lesser Scaup	*Aythya affinis*	LESC			x
Lesser Yellowlegs	*Tringa flavipes*	LEYE			
Lincoln's Sparrow	*Melospiza lincolnii*	LISP			
Magnolia Warbler	*Setophaga magnolia*	MAWA			
Mallard	*Anas platyrhynchos*	MALL			
Marsh Wren	*Cistothorus palustris*	MAWR			
Myrtle Warbler	*Setophaga coronata coronata*	MYWA			
Northern Flicker	*Colaptes auratus*	NOFL			
Northern Goshawk	*Accipiter gentilis*	NOGO			x
Northern Harrier	*Circus cyaneus*	NOHA			
Northern Shoveler	*Anas clypeata*	NOSH			
Northern Waterthrush	*Parkesia noveboracensis*	NOWA			
Ovenbird	*Seiurus aurocapilla*	OVEN			
Palm Warbler	*Setophaga palmarum*	PAWA			
Piliated Woodpecker	*Dryocopus pileatus*	PIWO			
Red-eyed Vireo	*Vireo olivaceus*	REVI			
Redhead Duck	*Aythya americana*	REDU			
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL	x	x	x
Ring-billed Gull	*Larus delawarensis*	RBGU			
Ring-necked Duck	*Aythya collaris*	RNDU			x
Savannah Sparrow	*Passerculus sandwichensis*	SASP			x
Solitary Sandpiper	*Tringa solitaria*	SOSA			
Song Sparrow	*Melospiza melodia*	SOSP			x
Sora	*Porzana carolina*	SORA			x
Spotted Sandpiper	*Actitis macularia*	SPSA			

Swainson's Thrush	*Catharus ustulatus*	SWTH		x	
Swamp Sparrow	*Melospiza georgiana*	SWSP			
Tree Swallow	*Tachycineta bicolor*	TRSW	x		x
Vesper Sparrow	*Pooecetes gramineus*	VESP	x		x
Western Wood Pewee	*Contopus sordidulus*	WWPE			
White-crowned Sparrow	*Zonotrichia leucophrys*	WCSP			
White-throated Sparrow	*Zonotrichia albicollis*	WTSP		x	x
Wilson's Snipe	*Gallinago delicata*	WISN			
Yellow Warbler	*Setophaga petechia*	YWAR		x	
Yellow-rumped Warbler	*Steophaga coronata*	YRWA			

		Wetland Name:	1mCT	Blueberry Wetland	4M CT
		Wetland Type:	y	n	y
		Wetland Area (ha)	0.4	0.44	0.51
Common Name	**Scientific Name**	**Acronym**			
American Coot	*Fulica americana*	AMCO			
American Crow	*Corvus brachyrhynchos*	AMCR			
American Kestrel	*Falco sparverius*	AMKE			
American Redstart	*Setophaga ruticilla*	AMRE			
American Robin	*Turdus migratorius*	AMRO		x	x
American Widgeon	*Anas americana*	AMWI			
Bald Eagle	*Haliaeetus leucocephalus*	BAEA			
Barn Swallow	*Hirundo rustica*	BASW			
Belted Kingfisher	*Megaceryle alcyon*	BEKI			
Black and White Warbler	*Mniotilta varia*	BAWW			
Black-billed Magpie	*Pica hudsonia*	BBMA	x		
Blackpoll Warbler	*Setophaga striata*	BPWA			
Blue-headed Vireo	*Vireo solitarius*	BHVI	x		
Blue-winged Teal	*Anas discors*	BWTE			x
Bonaparte's Gull	*Chroicocephalus philadelphia*	BOGU	x		
Boreal Chickadee	*Poecile hudsonicus*	BOCH			
Brown-headed Cowbird	*Molothrus ater*	BHCO			
Bufflehead	*Bucephala albeola*	BUFF			
Canada Goose	*Branta canadensis*	CAGO		x	
Canvasback	*Aythya valisineria*	CANV			
Chipping Sparrow	*Spizella passerina*	CHSP	x	x	x

Clay-coloured Sparrow	*Spizella pallida*	CCSP	x		
common Golden Eye	*Bucephala clangula*	COGO			
Common Grackle	*Quiscalus quiscula*	COGR	x		
Common Loon	*Gavia immer*	COLO	x		
Common Raven	*Corvus corax*	CORA			
Common Yellowthroat	*Geothlypis trichas*	COYE			
Gadwall	*Anas strepera*	GALD			
Gray Jay	*Perisoreus canadensis*	GRJA			
Greater Yellowlegs	*Tringa melanoleuca*	GRYE			
Green-Winged Teal	*Anas carolinensis*	GWTE			
Hermit Thrush	*Catharus guttatus*	HETH			
Herring Gull	*Larus argentatus*	HEGU			
Horned Grebe	*Podiceps auritus*	HOGR	x		
Killdeer	*Charadrius vociferus*	KILL			
Least Flycatcher	*Empidonax minimus*	LEFL			x
LeConte's Sparrow	*Ammodramus leconteii*	LCSP			
Lesser Scaup	*Aythya affinis*	LESC	x		
Lesser Yellowlegs	*Tringa flavipes*	LEYE			x
Lincoln's Sparrow	*Melospiza lincolnii*	LISP			
Magnolia Warbler	*Setophaga magnolia*	MAWA			
Mallard	*Anas platyrhynchos*	MALL			x
Marsh Wren	*Cistothorus palustris*	MAWR			
Myrtle Warbler	*Setophaga coronata coronata*	MYWA			
Northern Flicker	*Colaptes auratus*	NOFL		x	
Northern Goshawk	*Accipiter gentilis*	NOGO			
Northern Harrier	*Circus cyaneus*	NOHA			
Northern Shoveler	*Anas clypeata*	NOSH	x		
Northern Waterthrush	*Parkesia noveboracensis*	NOWA			
Ovenbird	*Seiurus aurocapilla*	OVEN			
Palm Warbler	*Setophaga palmarum*	PAWA			
Piliated Woodpecker	*Dryocopus pileatus*	PIWO		x	
Red-eyed Vireo	*Vireo olivaceus*	REVI			
Redhead Duck	*Aythya americana*	REDU			
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL	x		x
Ring-billed Gull	*Larus delawarensis*	RBGU			

Ring-necked Duck	*Aythya collaris*	RNDU			
Savannah Sparrow	*Passerculus sandwichensis*	SASP			
Solitary Sandpiper	*Tringa solitaria*	SOSA			
Song Sparrow	*Melospiza melodia*	SOSP	x		x
Sora	*Porzana carolina*	SORA	x		x
Spotted Sandpiper	*Actitis macularia*	SPSA			
Swainson's Thrush	*Catharus ustulatus*	SWTH		x	
Swamp Sparrow	*Melospiza georgiana*	SWSP		x	
Tree Swallow	*Tachycineta bicolor*	TRSW	x	x	x
Vesper Sparrow	*Pooecetes gramineus*	VESP		x	x
Western Wood Pewee	*Contopus sordidulus*	WWPE			
White-crowned Sparrow	*Zonotrichia leucophrys*	WCSP			
White-throated Sparrow	*Zonotrichia albicollis*	WTSP	x	x	x
Wilson's Snipe	*Gallinago delicata*	WISN			
Yellow Warbler	*Setophaga petechia*	YWAR		x	
Yellow-rumped Warbler	*Steophaga coronata*	YRWA			

		Wetland Name:	Crescent/Sand Pit	Bill's Pond	Golden Pond
		Wetland Type:	y	y	y
		Wetland Area (ha)	0.51	0.58	0.6
Common Name	**Scientific Name**	**Acronym**			
American Coot	*Fulica americana*	AMCO	x		
American Crow	*Corvus brachyrhynchos*	AMCR	x		x
American Kestrel	*Falco sparverius*	AMKE	x		
American Redstart	*Setophaga ruticilla*	AMRE			
American Robin	*Turdus migratorius*	AMRO	x		
American Widgeon	*Anas americana*	AMWI			
Bald Eagle	*Haliaeetus leucocephalus*	BAEA			
Barn Swallow	*Hirundo rustica*	BASW	x		
Belted Kingfisher	*Megaceryle alcyon*	BEKI			
Black and White Warbler	*Mniotilta varia*	BAWW			
Black-billed Magpie	*Pica hudsonia*	BBMA			
Blackpoll Warbler	*Setophaga striata*	BPWA			
Blue-headed Vireo	*Vireo solitarius*	BHVI			

Blue-winged Teal	*Anas discors*	BWTE			
Bonaparte's Gull	*Chroicocephalus philadelphia*	BOGU			
Boreal Chickadee	*Poecile hudsonicus*	BOCH		x	
Brown-headed Cowbird	*Molothrus ater*	BHCO			
Bufflehead	*Bucephala albeola*	BUFF			
Canada Goose	*Branta canadensis*	CAGO			
Canvasback	*Aythya valisineria*	CANV			
Chipping Sparrow	*Spizella passerina*	CHSP	x	x	x
Clay-coloured Sparrow	*Spizella pallida*	CCSP		x	x
common Golden Eye	*Bucephala clangula*	COGO			
Common Grackle	*Quiscalus quiscula*	COGR			
Common Loon	*Gavia immer*	COLO			
Common Raven	*Corvus corax*	CORA			
Common Yellowthroat	*Geothlypis trichas*	COYE			
Gadwall	*Anas strepera*	GALD			
Gray Jay	*Perisoreus canadensis*	GRJA			
Greater Yellowlegs	*Tringa melanoleuca*	GRYE			
Green-Winged Teal	*Anas carolinensis*	GWTE			
Hermit Thrush	*Catharus guttatus*	HETH			
Herring Gull	*Larus argentatus*	HEGU			x
Horned Grebe	*Podiceps auritus*	HOGR			
Killdeer	*Charadrius vociferus*	KILL			
Least Flycatcher	*Empidonax minimus*	LEFL			
LeConte's Sparrow	*Ammodramus leconteii*	LCSP	x		
Lesser Scaup	*Aythya affinis*	LESC	x		x
Lesser Yellowlegs	*Tringa flavipes*	LEYE			
Lincoln's Sparrow	*Melospiza lincolnii*	LISP			x
Magnolia Warbler	*Setophaga magnolia*	MAWA			
Mallard	*Anas platyrhynchos*	MALL			
Marsh Wren	*Cistothorus palustris*	MAWR			
Myrtle Warbler	*Setophaga coronata coronata*	MYWA			
Northern Flicker	*Colaptes auratus*	NOFL		x	
Northern Goshawk	*Accipiter gentilis*	NOGO			
Northern Harrier	*Circus cyaneus*	NOHA			

Northern Shoveler	*Anas clypeata*	NOSH			
Northern Waterthrush	*Parkesia noveboracensis*	NOWA			
Ovenbird	*Seiurus aurocapilla*	OVEN			
Palm Warbler	*Setophaga palmarum*	PAWA			
Piliated Woodpecker	*Dryocopus pileatus*	PIWO			
Red-eyed Vireo	*Vireo olivaceus*	REVI		x	x
Redhead Duck	*Aythya americana*	REDU			x
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL	x	x	x
Ring-billed Gull	*Larus delawarensis*	RBGU			
Ring-necked Duck	*Aythya collaris*	RNDU			x
Savannah Sparrow	*Passerculus sandwichensis*	SASP			
Solitary Sandpiper	*Tringa solitaria*	SOSA			
Song Sparrow	*Melospiza melodia*	SOSP	x	x	x
Sora	*Porzana carolina*	SORA	x	x	x
Spotted Sandpiper	*Actitis macularia*	SPSA			
Swainson's Thrush	*Catharus ustulatus*	SWTH			
Swamp Sparrow	*Melospiza georgiana*	SWSP	x	x	
Tree Swallow	*Tachycineta bicolor*	TRSW	x	x	
Vesper Sparrow	*Pooecetes gramineus*	VESP			
Western Wood Pewee	*Contopus sordidulus*	WWPE			
White-crowned Sparrow	*Zonotrichia leucophrys*	WCSP			
White-throated Sparrow	*Zonotrichia albicollis*	WTSP	x	x	
Wilson's Snipe	*Gallinago delicata*	WISN			
Yellow Warbler	*Setophaga petechia*	YWAR	x	x	x
Yellow-rumped Warbler	*Steophaga coronata*	YRWA			

		Wetland Name:	Duck Pond	Peat Pond	Red Jacket
		Wetland Type:	y	y	n
		Wetland Area (ha)	0.67	0.75	0.93
Common Name	**Scientific Name**	**Acronym**			
American Coot	*Fulica americana*	AMCO			
American Crow	*Corvus brachyrhynchos*	AMCR	x	x	

American Kestrel	*Falco sparverius*	AMKE			
American Redstart	*Setophaga ruticilla*	AMRE			
American Robin	*Turdus migratorius*	AMRO	x	x	x
American Widgeon	*Anas americana*	AMWI		x	x
Bald Eagle	*Haliaeetus leucocephalus*	BAEA			
Barn Swallow	*Hirundo rustica*	BASW			
Belted Kingfisher	*Megaceryle alcyon*	BEKI			
Black and White Warbler	*Mniotilta varia*	BAWW			
Black-billed Magpie	*Pica hudsonia*	BBMA	x		
Blackpoll Warbler	*Setophaga striata*	BPWA			
Blue-headed Vireo	*Vireo solitarius*	BHVI			
Blue-winged Teal	*Anas discors*	BWTE			x
Bonaparte's Gull	*Chroicocephalus philadelphia*	BOGU	x		
Boreal Chickadee	*Poecile hudsonicus*	BOCH			
Brown-headed Cowbird	*Molothrus ater*	BHCO			x
Bufflehead	*Bucephala albeola*	BUFF		x	x
Canada Goose	*Branta canadensis*	CAGO			
Canvasback	*Aythya valisineria*	CANV	x		
Chipping Sparrow	*Spizella passerina*	CHSP		x	x
Clay-coloured Sparrow	*Spizella pallida*	CCSP		x	
common Golden Eye	*Bucephala clangula*	COGO			x
Common Grackle	*Quiscalus quiscula*	COGR			
Common Loon	*Gavia immer*	COLO			
Common Raven	*Corvus corax*	CORA	x		
Common Yellowthroat	*Geothlypis trichas*	COYE			
Gadwall	*Anas strepera*	GALD			
Gray Jay	*Perisoreus canadensis*	GRJA			x
Greater Yellowlegs	*Tringa melanoleuca*	GRYE			x
Green-Winged Teal	*Anas carolinensis*	GWTE			
Hermit Thrush	*Catharus guttatus*	HETH			
Herring Gull	*Larus argentatus*	HEGU		x	
Horned Grebe	*Podiceps auritus*	HOGR	x		
Killdeer	*Charadrius vociferus*	KILL	x		

Least Flycatcher	*Empidonax minimus*	LEFL			
LeConte's Sparrow	*Ammodramus leconteii*	LCSP			
Lesser Scaup	*Aythya affinis*	LESC	x		
Lesser Yellowlegs	*Tringa flavipes*	LEYE			x
Lincoln's Sparrow	*Melospiza lincolnii*	LISP		x	
Magnolia Warbler	*Setophaga magnolia*	MAWA			
Mallard	*Anas platyrhynchos*	MALL			
Marsh Wren	*Cistothorus palustris*	MAWR			
Myrtle Warbler	*Setophaga coronata coronata*	MYWA			
Northern Flicker	*Colaptes auratus*	NOFL			
Northern Goshawk	*Accipiter gentilis*	NOGO			
Northern Harrier	*Circus cyaneus*	NOHA		x	
Northern Shoveler	*Anas clypeata*	NOSH	x		
Northern Waterthrush	*Parkesia noveboracensis*	NOWA			
Ovenbird	*Seiurus aurocapilla*	OVEN			
Palm Warbler	*Setophaga palmarum*	PAWA			
Piliated Woodpecker	*Dryocopus pileatus*	PIWO			
Red-eyed Vireo	*Vireo olivaceus*	REVI			
Redhead Duck	*Aythya americana*	REDU			
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL	x		
Ring-billed Gull	*Larus delawarensis*	RBGU			
Ring-necked Duck	*Aythya collaris*	RNDU	x		x
Savannah Sparrow	*Passerculus sandwichensis*	SASP	x		x
Solitary Sandpiper	*Tringa solitaria*	SOSA			
Song Sparrow	*Melospiza melodia*	SOSP			
Sora	*Porzana carolina*	SORA	x		
Spotted Sandpiper	*Actitis macularia*	SPSA			x
Swainson's Thrush	*Catharus ustulatus*	SWTH			
Swamp Sparrow	*Melospiza georgiana*	SWSP			x
Tree Swallow	*Tachycineta bicolor*	TRSW			
Vesper Sparrow	*Pooecetes gramineus*	VESP	x		x
Western Wood Pewee	*Contopus sordidulus*	WWPE			
White-crowned Sparrow	*Zonotrichia leucophrys*	WCSP			

White-throated Sparrow	*Zonotrichia albicollis*	WTSP	x	x
Wilson's Snipe	*Gallinago delicata*	WISN		
Yellow Warbler	*Setophaga petechia*	YWAR	x	
Yellow-rumped Warbler	*Steophaga coronata*	YRWA		

		Wetland Name:	MFT North and South	Natural Wetland	Sam's Rodeo
		Wetland Type:	y	y	n
		Wetland Area (ha)	1.07	1.16	1.91
Common Name	**Scientific Name**	**Acronym**			
American Coot	*Fulica americana*	AMCO			
American Crow	*Corvus brachyrhynchos*	AMCR		x	x
American Kestrel	*Falco sparverius*	AMKE			
American Redstart	*Setophaga ruticilla*	AMRE			
American Robin	*Turdus migratorius*	AMRO	x		x
American Widgeon	*Anas americana*	AMWI		x	
Bald Eagle	*Haliaeetus leucocephalus*	BAEA			
Barn Swallow	*Hirundo rustica*	BASW			x
Belted Kingfisher	*Megaceryle alcyon*	BEKI			x
Black and White Warbler	*Mniotilta varia*	BAWW			
Black-billed Magpie	*Pica hudsonia*	BBMA	x	x	x
Blackpoll Warbler	*Setophaga striata*	BPWA			
Blue-headed Vireo	*Vireo solitarius*	BHVI			
Blue-winged Teal	*Anas discors*	BWTE			
Bonaparte's Gull	*Chroicocephalus philadelphia*	BOGU			
Boreal Chickadee	*Poecile hudsonicus*	BOCH			
Brown-headed Cowbird	*Molothrus ater*	BHCO			x
Bufflehead	*Bucephala albeola*	BUFF	x	x	
Canada Goose	*Branta canadensis*	CAGO		x	
Canvasback	*Aythya valisineria*	CANV	x		
Chipping Sparrow	*Spizella passerina*	CHSP	x	x	x
Clay-coloured Sparrow	*Spizella pallida*	CCSP	x		

common Golden Eye	*Bucephala clangula*	COGO			
Common Grackle	*Quiscalus quiscula*	COGR			
Common Loon	*Gavia immer*	COLO			
Common Raven	*Corvus corax*	CORA	x		
Common Yellowthroat	*Geothlypis trichas*	COYE			
Gadwall	*Anas strepera*	GALD		x	
Gray Jay	*Perisoreus canadensis*	GRJA			x
Greater Yellowlegs	*Tringa melanoleuca*	GRYE			
Green-Winged Teal	*Anas carolinensis*	GWTE		x	
Hermit Thrush	*Catharus guttatus*	HETH			
Herring Gull	*Larus argentatus*	HEGU			
Horned Grebe	*Podiceps auritus*	HOGR			
Killdeer	*Charadrius vociferus*	KILL			
Least Flycatcher	*Empidonax minimus*	LEFL			
LeConte's Sparrow	*Ammodramus leconteii*	LCSP			
Lesser Scaup	*Aythya affinis*	LESC		x	
Lesser Yellowlegs	*Tringa flavipes*	LEYE			
Lincoln's Sparrow	*Melospiza lincolnii*	LISP			
Magnolia Warbler	*Setophaga magnolia*	MAWA			
Mallard	*Anas platyrhynchos*	MALL		x	
Marsh Wren	*Cistothorus palustris*	MAWR			
Myrtle Warbler	*Setophaga coronata coronata*	MYWA			
Northern Flicker	*Colaptes auratus*	NOFL			x
Northern Goshawk	*Accipiter gentilis*	NOGO			
Northern Harrier	*Circus cyaneus*	NOHA			x
Northern Shoveler	*Anas clypeata*	NOSH		x	
Northern Waterthrush	*Parkesia noveboracensis*	NOWA			
Ovenbird	*Seiurus aurocapilla*	OVEN			
Palm Warbler	*Setophaga palmarum*	PAWA			
Piliated Woodpecker	*Dryocopus pileatus*	PIWO			
Red-eyed Vireo	*Vireo olivaceus*	REVI			
Redhead Duck	*Aythya americana*	REDU			
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL		x	x
Ring-billed Gull	*Larus delawarensis*	RBGU			x
Ring-necked Duck	*Aythya collaris*	RNDU			

Savannah Sparrow	*Passerculus sandwichensis*	SASP			
Solitary Sandpiper	*Tringa solitaria*	SOSA			
Song Sparrow	*Melospiza melodia*	SOSP			
Sora	*Porzana carolina*	SORA		x	x
Spotted Sandpiper	*Actitis macularia*	SPSA			
Swainson's Thrush	*Catharus ustulatus*	SWTH	x		
Swamp Sparrow	*Melospiza georgiana*	SWSP		x	
Tree Swallow	*Tachycineta bicolor*	TRSW		x	x
Vesper Sparrow	*Pooecetes gramineus*	VESP			x
Western Wood Pewee	*Contopus sordidulus*	WWPE			
White-crowned Sparrow	*Zonotrichia leucophrys*	WCSP			
White-throated Sparrow	*Zonotrichia albicollis*	WTSP	x	x	x
Wilson's Snipe	*Gallinago delicata*	WISN			x
Yellow Warbler	*Setophaga petechia*	YWAR		x	x
Yellow-rumped Warbler	*Steophaga coronata*	YRWA			

		Wetland Name:	N1 Wetland	Seepage	Demo	Shallow Wetland	Muskeg
		Wetland Type:	n	y	y	y	n
		Wetland Area (ha)	2.11	2.42	2.46	2.75	3.22
Common Name	**Scientific Name**	**Acronym**					
American Coot	*Fulica americana*	AMCO					
American Crow	*Corvus brachyrhynchos*	AMCR		x		x	
American Kestrel	*Falco sparverius*	AMKE					
American Redstart	*Setophaga ruticilla*	AMRE					
American Robin	*Turdus migratorius*	AMRO	x		x		x
American Widgeon	*Anas americana*	AMWI		x	x	x	
Bald Eagle	*Haliaeetus leucocephalus*	BAEA					
Barn Swallow	*Hirundo rustica*	BASW					
Belted Kingfisher	*Megaceryle alcyon*	BEKI					
Black and White Warbler	*Mniotilta varia*	BAWW					
Black-billed Magpie	*Pica hudsonia*	BBMA	x		x	x	

Blackpoll Warbler	*Setophaga striata*	BPWA					
Blue-headed Vireo	*Vireo solitarius*	BHVI					
Blue-winged Teal	*Anas discors*	BWTE					
Bonaparte's Gull	*Chroicocephalus philadelphia*	BOGU					
Boreal Chickadee	*Poecile hudsonicus*	BOCH					
Brown-headed Cowbird	*Molothrus ater*	BHCO	x			x	x
Bufflehead	*Bucephala albeola*	BUFF		x			x
Canada Goose	*Branta canadensis*	CAGO		x		x	
Canvasback	*Aythya valisineria*	CANV					
Chipping Sparrow	*Spizella passerina*	CHSP	x	x			
Clay-coloured Sparrow	*Spizella pallida*	CCSP		x		x	
common Golden Eye	*Bucephala clangula*	COGO					x
Common Grackle	*Quiscalus quiscula*	COGR					x
Common Loon	*Gavia immer*	COLO					
Common Raven	*Corvus corax*	CORA	x	x			x
Common Yellowthroat	*Geothlypis trichas*	COYE				x	
Gadwall	*Anas strepera*	GALD		x			
Gray Jay	*Perisoreus canadensis*	GRJA					
Greater Yellowlegs	*Tringa melanoleuca*	GRYE			x		
Green-Winged Teal	*Anas carolinensis*	GWTE	x	x			
Hermit Thrush	*Catharus guttatus*	HETH					
Herring Gull	*Larus argentatus*	HEGU					
Horned Grebe	*Podiceps auritus*	HOGR			x		
Killdeer	*Charadrius vociferus*	KILL					x
Least Flycatcher	*Empidonax minimus*	LEFL					
LeConte's Sparrow	*Ammodramus leconteii*	LCSP			x		
Lesser Scaup	*Aythya affinis*	LESC		x			
Lesser Yellowlegs	*Tringa flavipes*	LEYE					
Lincoln's Sparrow	*Melospiza lincolnii*	LISP					
Magnolia Warbler	*Setophaga magnolia*	MAWA					x
Mallard	*Anas platyrhynchos*	MALL		x		x	x
Marsh Wren	*Cistothorus palustris*	MAWR				x	
Myrtle Warbler	*Setophaga coronata coronata*	MYWA					
Northern Flicker	*Colaptes auratus*	NOFL	x				

Northern Goshawk	*Accipiter gentilis*	NOGO					
Northern Harrier	*Circus cyaneus*	NOHA					
Northern Shoveler	*Anas clypeata*	NOSH			x	x	
Northern Waterthrush	*Parkesia noveboracensis*	NOWA					
Ovenbird	*Seiurus aurocapilla*	OVEN					
Palm Warbler	*Setophaga palmarum*	PAWA					
Piliated Woodpecker	*Dryocopus pileatus*	PIWO					
Red-eyed Vireo	*Vireo olivaceus*	REVI		x	x	x	
Redhead Duck	*Aythya americana*	REDU					
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL	x	x	x	x	x
Ring-billed Gull	*Larus delawarensis*	RBGU					
Ring-necked Duck	*Aythya collaris*	RNDU		x			
Savannah Sparrow	*Passerculus sandwichensis*	SASP	x				x
Solitary Sandpiper	*Tringa solitaria*	SOSA					
Song Sparrow	*Melospiza melodia*	SOSP		x	x	x	x
Sora	*Porzana carolina*	SORA		x	x	x	x
Spotted Sandpiper	*Actitis macularia*	SPSA			x		
Swainson's Thrush	*Catharus ustulatus*	SWTH					
Swamp Sparrow	*Melospiza georgiana*	SWSP				x	x
Tree Swallow	*Tachycineta bicolor*	TRSW		x	x		
Vesper Sparrow	*Pooecetes gramineus*	VESP					
Western Wood Pewee	*Contopus sordidulus*	WWPE					
White-crowned Sparrow	*Zonotrichia leucophrys*	WCSP					
White-throated Sparrow	*Zonotrichia albicollis*	WTSP	x	x		x	x
Wilson's Snipe	*Gallinago delicata*	WISN					
Yellow Warbler	*Setophaga petechia*	YWAR	x	x	x	x	
Yellow-rumped Warbler	*Steophaga coronata*	YRWA					
		Wetland Name:	Floodplain	N20 Moose	High Sulphate	Hidden Wetland	Beaver Lodge
		Wetland Type:	y	n	y	n	n
		Wetland Area (ha)	3.3	3.39	4	5	5.08
Common Name	**Scientific Name**	**Acronym**					

American Coot	*Fulica americana*	AMCO					
American Crow	*Corvus brachyrhynchos*	AMCR					
American Kestrel	*Falco sparverius*	AMKE					
American Redstart	*Setophaga ruticilla*	AMRE					
American Robin	*Turdus migratorius*	AMRO	x	x	x		x
American Widgeon	*Anas americana*	AMWI					x
Bald Eagle	*Haliaeetus leucocephalus*	BAEA					
Barn Swallow	*Hirundo rustica*	BASW					
Belted Kingfisher	*Megaceryle alcyon*	BEKI					
Black and White Warbler	*Mniotilta varia*	BAWW	x				
Black-billed Magpie	*Pica hudsonia*	BBMA	x	x	x		
Blackpoll Warbler	*Setophaga striata*	BPWA					
Blue-headed Vireo	*Vireo solitarius*	BHVI					
Blue-winged Teal	*Anas discors*	BWTE					x
Bonaparte's Gull	*Chroicocephalus philadelphia*	BOGU					x
Boreal Chickadee	*Poecile hudsonicus*	BOCH	x		x	x	
Brown-headed Cowbird	*Molothrus ater*	BHCO		x		x	x
Bufflehead	*Bucephala albeola*	BUFF	x				x
Canada Goose	*Branta canadensis*	CAGO		x			
Canvasback	*Aythya valisineria*	CANV			x		
Chipping Sparrow	*Spizella passerina*	CHSP	x	x	x	x	x
Clay-coloured Sparrow	*Spizella pallida*	CCSP	x				
common Golden Eye	*Bucephala clangula*	COGO					
Common Grackle	*Quiscalus quiscula*	COGR				x	
Common Loon	*Gavia immer*	COLO	x				
Common Raven	*Corvus corax*	CORA					
Common Yellowthroat	*Geothlypis trichas*	COYE	x				x
Gadwall	*Anas strepera*	GALD					
Gray Jay	*Perisoreus canadensis*	GRJA					
Greater Yellowlegs	*Tringa melanoleuca*	GRYE					
Green-Winged Teal	*Anas carolinensis*	GWTE					x
Hermit Thrush	*Catharus guttatus*	HETH					
Herring Gull	*Larus argentatus*	HEGU					

Horned Grebe	*Podiceps auritus*	HOGR					
Killdeer	*Charadrius vociferus*	KILL		x			x
Least Flycatcher	*Empidonax minimus*	LEFL					
LeConte's Sparrow	*Ammodramus leconteii*	LCSP			x		
Lesser Scaup	*Aythya affinis*	LESC			x	x	
Lesser Yellowlegs	*Tringa flavipes*	LEYE					
Lincoln's Sparrow	*Melospiza lincolnii*	LISP					
Magnolia Warbler	*Setophaga magnolia*	MAWA	x		x		
Mallard	*Anas platyrhynchos*	MALL					x
Marsh Wren	*Cistothorus palustris*	MAWR					
Myrtle Warbler	*Setophaga coronata coronata*	MYWA		x	x	x	
Northern Flicker	*Colaptes auratus*	NOFL		x		x	
Northern Goshawk	*Accipiter gentilis*	NOGO					
Northern Harrier	*Circus cyaneus*	NOHA					
Northern Shoveler	*Anas clypeata*	NOSH					
Northern Waterthrush	*Parkesia noveboracensis*	NOWA					
Ovenbird	*Seiurus aurocapilla*	OVEN					
Palm Warbler	*Setophaga palmarum*	PAWA					
Piliated Woodpecker	*Dryocopus pileatus*	PIWO					
Red-eyed Vireo	*Vireo olivaceus*	REVI	x				
Redhead Duck	*Aythya americana*	REDU					
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL		x	x	x	x
Ring-billed Gull	*Larus delawarensis*	RBGU					
Ring-necked Duck	*Aythya collaris*	RNDU					
Savannah Sparrow	*Passerculus sandwichensis*	SASP		x		x	
Solitary Sandpiper	*Tringa solitaria*	SOSA					x
Song Sparrow	*Melospiza melodia*	SOSP	x	x		x	
Sora	*Porzana carolina*	SORA					x
Spotted Sandpiper	*Actitis macularia*	SPSA					x
Swainson's Thrush	*Catharus ustulatus*	SWTH					
Swamp Sparrow	*Melospiza georgiana*	SWSP		x			x
Tree Swallow	*Tachycineta bicolor*	TRSW					x
Vesper Sparrow	*Pooecetes gramineus*	VESP					x
Western Wood Pewee	*Contopus sordidulus*	WWPE				x	

White-crowned Sparrow	*Zonotrichia leucophrys*	WCSP					
White-throated Sparrow	*Zonotrichia albicollis*	WTSP	x	x	x	x	
Wilson's Snipe	*Gallinago delicata*	WISN					x
Yellow Warbler	*Setophaga petechia*	YWAR	x				
Yellow-rumped Warbler	*Steophaga coronata*	YRWA					

		Wetland Name:	Rhino's Wateringhole	Loon Lake/Weir 1	HammerStakeBeaver	Jule's Wetland
		Wetland Type:	n	y	n	n
		Wetland Area (ha)	5.21	5.62	7.8	12.7
Common Name	**Scientific Name**	**Acronym**				
American Coot	*Fulica americana*	AMCO	x			x
American Crow	*Corvus brachyrhynchos*	AMCR	x	x		
American Kestrel	*Falco sparverius*	AMKE				
American Redstart	*Setophaga ruticilla*	AMRE				
American Robin	*Turdus migratorius*	AMRO	x	x		x
American Widgeon	*Anas americana*	AMWI				x
Bald Eagle	*Haliaeetus leucocephalus*	BAEA				
Barn Swallow	*Hirundo rustica*	BASW				
Belted Kingfisher	*Megaceryle alcyon*	BEKI				
Black and White Warbler	*Mniotilta varia*	BAWW				
Black-billed Magpie	*Pica hudsonia*	BBMA			x	
Blackpoll Warbler	*Setophaga striata*	BPWA				
Blue-headed Vireo	*Vireo solitarius*	BHVI				
Blue-winged Teal	*Anas discors*	BWTE				x
Bonaparte's Gull	*Chroicocephalus philadelphia*	BOGU		x		x
Boreal Chickadee	*Poecile hudsonicus*	BOCH				
Brown-headed Cowbird	*Molothrus ater*	BHCO				
Bufflehead	*Bucephala albeola*	BUFF	x			x
Canada Goose	*Branta canadensis*	CAGO				
Canvasback	*Aythya valisineria*	CANV				
Chipping Sparrow	*Spizella passerina*	CHSP	x	x	x	

Clay-coloured Sparrow	*Spizella pallida*	CCSP				
common Golden Eye	*Bucephala clangula*	COGO	x			
Common Grackle	*Quiscalus quiscula*	COGR	x			
Common Loon	*Gavia immer*	COLO		x		
Common Raven	*Corvus corax*	CORA				
Common Yellowthroat	*Geothlypis trichas*	COYE				x
Gadwall	*Anas strepera*	GALD				
Gray Jay	*Perisoreus canadensis*	GRJA				
Greater Yellowlegs	*Tringa melanoleuca*	GRYE		x		x
Green-Winged Teal	*Anas carolinensis*	GWTE	x			x
Hermit Thrush	*Catharus guttatus*	HETH			x	
Herring Gull	*Larus argentatus*	HEGU	x			
Horned Grebe	*Podiceps auritus*	HOGR				
Killdeer	*Charadrius vociferus*	KILL				
Least Flycatcher	*Empidonax minimus*	LEFL				
LeConte's Sparrow	*Ammodramus leconteii*	LCSP				
Lesser Scaup	*Aythya affinis*	LESC				
Lesser Yellowlegs	*Tringa flavipes*	LEYE	x			x
Lincoln's Sparrow	*Melospiza lincolnii*	LISP				
Magnolia Warbler	*Setophaga magnolia*	MAWA				
Mallard	*Anas platyrhynchos*	MALL	x	x		x
Marsh Wren	*Cistothorus palustris*	MAWR				
Myrtle Warbler	*Setophaga coronata coronata*	MYWA				
Northern Flicker	*Colaptes auratus*	NOFL				
Northern Goshawk	*Accipiter gentilis*	NOGO				
Northern Harrier	*Circus cyaneus*	NOHA				
Northern Shoveler	*Anas clypeata*	NOSH				x
Northern Waterthrush	*Parkesia noveboracensis*	NOWA				
Ovenbird	*Seiurus aurocapilla*	OVEN			x	
Palm Warbler	*Setophaga palmarum*	PAWA				
Piliated Woodpecker	*Dryocopus pileatus*	PIWO				
Red-eyed Vireo	*Vireo olivaceus*	REVI				
Redhead Duck	*Aythya americana*	REDU				
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL	x	x		x
Ring-billed Gull	*Larus delawarensis*	RBGU				

Ring-necked Duck	*Aythya collaris*	RNDU	x	x		
Savannah Sparrow	*Passerculus sandwichensis*	SASP			x	
Solitary Sandpiper	*Tringa solitaria*	SOSA				x
Song Sparrow	*Melospiza melodia*	SOSP				
Sora	*Porzana carolina*	SORA	x			x
Spotted Sandpiper	*Actitis macularia*	SPSA				x
Swainson's Thrush	*Catharus ustulatus*	SWTH				
Swamp Sparrow	*Melospiza georgiana*	SWSP	x		x	x
Tree Swallow	*Tachycineta bicolor*	TRSW		x		
Vesper Sparrow	*Pooecetes gramineus*	VESP		x		
Western Wood Pewee	*Contopus sordidulus*	WWPE				
White-crowned Sparrow	*Zonotrichia leucophrys*	WCSP				
White-throated Sparrow	*Zonotrichia albicollis*	WTSP	x	x	x	x
Wilson's Snipe	*Gallinago delicata*	WISN	x			x
Yellow Warbler	*Setophaga petechia*	YWAR	x		x	x
Yellow-rumped Warbler	*Steophaga coronata*	YRWA				

		Wetland Name:	Crane Lake	Sheeva's Wetland	Shipyard Lake
		Wetland Type:	y	n	n
		Wetland Area (ha)	22.6	40	151
Common Name	**Scientific Name**	**Acronym**			
American Coot	*Fulica americana*	AMCO	x		
American Crow	*Corvus brachyrhynchos*	AMCR			
American Kestrel	*Falco sparverius*	AMKE			x
American Redstart	*Setophaga ruticilla*	AMRE	x		
American Robin	*Turdus migratorius*	AMRO	x		x
American Widgeon	*Anas americana*	AMWI			
Bald Eagle	*Haliaeetus leucocephalus*	BAEA		x	
Barn Swallow	*Hirundo rustica*	BASW			
Belted Kingfisher	*Megaceryle alcyon*	BEKI			
Black and White Warbler	*Mniotilta varia*	BAWW			

Black-billed Magpie	*Pica hudsonia*	BBMA			
Blackpoll Warbler	*Setophaga striata*	BPWA	x		
Blue-headed Vireo	*Vireo solitarius*	BHVI			
Blue-winged Teal	*Anas discors*	BWTE			x
Bonaparte's Gull	*Chroicocephalus philadelphia*	BOGU			x
Boreal Chickadee	*Poecile hudsonicus*	BOCH	x		x
Brown-headed Cowbird	*Molothrus ater*	BHCO		x	x
Bufflehead	*Bucephala albeola*	BUFF		x	x
Canada Goose	*Branta canadensis*	CAGO			x
Canvasback	*Aythya valisineria*	CANV			
Chipping Sparrow	*Spizella passerina*	CHSP			
Clay-coloured Sparrow	*Spizella pallida*	CCSP	x		
common Golden Eye	*Bucephala clangula*	COGO	x		
Common Grackle	*Quiscalus quiscula*	COGR			x
Common Loon	*Gavia immer*	COLO			
Common Raven	*Corvus corax*	CORA			
Common Yellowthroat	*Geothlypis trichas*	COYE			
Gadwall	*Anas strepera*	GALD			
Gray Jay	*Perisoreus canadensis*	GRJA			x
Greater Yellowlegs	*Tringa melanoleuca*	GRYE			x
Green-Winged Teal	*Anas carolinensis*	GWTE			x
Hermit Thrush	*Catharus guttatus*	HETH			
Herring Gull	*Larus argentatus*	HEGU			x
Horned Grebe	*Podiceps auritus*	HOGR			
Killdeer	*Charadrius vociferus*	KILL	x	x	
Least Flycatcher	*Empidonax minimus*	LEFL			
LeConte's Sparrow	*Ammodramus leconteii*	LCSP	x		
Lesser Scaup	*Aythya affinis*	LESC		x	
Lesser Yellowlegs	*Tringa flavipes*	LEYE		x	
Lincoln's Sparrow	*Melospiza lincolnii*	LISP			
Magnolia Warbler	*Setophaga magnolia*	MAWA	x		
Mallard	*Anas platyrhynchos*	MALL	x	x	
Marsh Wren	*Cistothorus palustris*	MAWR			
Myrtle Warbler	*Setophaga coronata coronata*	MYWA			

Northern Flicker	*Colaptes auratus*	NOFL			
Northern Goshawk	*Accipiter gentilis*	NOGO			
Northern Harrier	*Circus cyaneus*	NOHA			
Northern Shoveler	*Anas clypeata*	NOSH	x		
Northern Waterthrush	*Parkesia noveboracensis*	NOWA			x
Ovenbird	*Seiurus aurocapilla*	OVEN			
Palm Warbler	*Setophaga palmarum*	PAWA	x		
Piliated Woodpecker	*Dryocopus pileatus*	PIWO			
Red-eyed Vireo	*Vireo olivaceus*	REVI			
Redhead Duck	*Aythya americana*	REDU	x		
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL	x	x	x
Ring-billed Gull	*Larus delawarensis*	RBGU			
Ring-necked Duck	*Aythya collaris*	RNDU		x	
Savannah Sparrow	*Passerculus sandwichensis*	SASP	x	x	x
Solitary Sandpiper	*Tringa solitaria*	SOSA			
Song Sparrow	*Melospiza melodia*	SOSP			x
Sora	*Porzana carolina*	SORA	x	x	
Spotted Sandpiper	*Actitis macularia*	SPSA		x	
Swainson's Thrush	*Catharus ustulatus*	SWTH			
Swamp Sparrow	*Melospiza georgiana*	SWSP			
Tree Swallow	*Tachycineta bicolor*	TRSW	x		x
Vesper Sparrow	*Pooecetes gramineus*	VESP			x
Western Wood Pewee	*Contopus sordidulus*	WWPE			
White-crowned Sparrow	*Zonotrichia leucophrys*	WCSP	x		
White-throated Sparrow	*Zonotrichia albicollis*	WTSP	x	x	x
Wilson's Snipe	*Gallinago delicata*	WISN			
Yellow Warbler	*Setophaga petechia*	YWAR	x		
Yellow-rumped Warbler	*Steophaga coronata*	YRWA	x		

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