University of Alberta

Habitat selection and food-web relations of Horned Grebes (*Podiceps auritus*) and other aquatic birds on constructed wetlands in the Peace Parkland, Alberta, Canada

by

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Abstract

I investigated if constructed wetlands provide breeding habitat for the Horned Grebe (*Podiceps auritus*) in northwest Alberta. Over two years, I conducted bird surveys of 201 borrow-pits (ponds created during road construction) and 18 natural wetlands and collected data on local habitat and landscape features. For subsets of ponds, I also collected water chemistry and invertebrate data, and conducted stable isotope analysis. Grebes occurred on 36% of borrow-pits and produced chicks on 61% of occupied sites in 2007 and 81% in 2008. Grebes occurred more frequently on larger ponds, with more emergent vegetation, and avoided forested ponds that supported beaver activity. Horned Grebes are generalist foragers that did not select nesting ponds based on food-web structure. Twenty-six other bird species used borrow-pits, with distinct assemblages occurring on agricultural versus forested ponds. My study indicates that wetland construction offers a viable method for creating habitat for Horned Grebes and other species.

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Chapter 1

Introduction

A question that has been posed many times in ecological research is why and how does a species choose one location over another in which to live, forage or breed (see Bernstein et al. 1991 and Rosenzweig 1991 for reviews). The result of this choice has great consequences, evident through the reproductive productivity of an individual within a species; presumably individuals will try and maximize their success by selecting sites based on certain characteristics that will improve their chances of reproduction, and avoid others that will not. Theoretically, individuals should distribute themselves across a landscape in proportion to the amount of available resources (Fretwell and Lucas 1970), until all possible habitat patches are saturated. However, rarely are systems so simple; there are many additional factors at play. Intraspecific competition, through territoriality, might force subordinate or late arriving individuals into poorer quality habitat (Fretwell 1972); individuals within a species will then use a wider range of habitat than they would in the absence of competition. The introduction of a second species to this system, through interspecific competition, can then induce habitat selection where it was previously absent (Svardson 1949). An understanding of what habitat characteristics benefit a species, as well as influence species distributions among different habitats, can thus aid in habitat protection for a species of conservation concern and potentially protect additional species utilizing the same general habitat as well.

Migratory birds are frequently used in studies of habitat selection as they are highly mobile and select breeding habitat year after year (Cody 1981, Bernstein et al. 1991). Here I study one particular case of habitat selection by the Horned Grebe (*Podiceps auritus*) that frequently occupies small wetlands for summer breeding habitat.

Study species

The Horned Grebe is a small, non-game migratory waterbird in the family of Podicipedidae, which contains 22 species of grebes in six genera. Six of these species are found in Canada (Vlug and Fjeldså 1990). There are two recognized subspecies of Horned Grebes, *Podiceps auritus auritus* is found in western Eurasia, including northern Europe, the Baltic region and Russia. *Podiceps auritus cornutus* is a North American subspecies (Fjeldså 1973a). The breeding and wintering ranges of the North American Horned Grebe population are depicted in Figure 1.1. Breeding occurs on permanent, shallow bodies of water in western Canada (Manitoba to eastern British Columbia and north to the Yukon and Northwest Territories) and the northwestern United States in the prairies and parklands, north to Alaska (Fjeldså 1973a). A small population also breeds in Quebec (Stedman 2000). Male and female Horned Grebes form pair bonds during spring migration from coastal areas and create floating nests anchored to emergent vegetation in small wetlands once they reach the breeding grounds (Stedman 2000). Horned Grebes feed primarily on aquatic macroinvertebrates during the breeding season, switching to a piscivorous diet in coastal over-wintering areas (Fisher and Acorn 1998, Stedman 2000), thus exploiting locally and temporally available prey (Fjeldså 1973b). As they are largely restricted to breeding wetlands, they are sensitive to changes in habitat quality; the presence and success of grebes has been proposed as being potentially useful for the identification of valuable wetland habitat (Vlug and Fjeldså 1990, O'Donnell and Fjeldså 1997).

Although it has a wide distribution, the species is declining (particularly *P. a. cornutus*, but possibly *P. a. auritus* in some locations; O'Donnell and Fjeldså 1997), likely as a result of the loss and degradation of wetland breeding habitat due to agriculture, drought, and various types of contamination. Viable breeding habitat for this species in North America is shrinking and retreating north-westward (Downes and Collins 2008). Breeding bird surveys have found that Horned Grebes declined at a rate of 2.7% per year Canada-wide from 1968-2007. This rate of decline is higher when looking at Alberta alone, at 7.3% per year from 1968-2007 (Downes and Collins 2008). The Horned Grebe is now listed as a species of high concern by the Northern Prairie and Parkland Waterbird Conservation Plan (Beyersbergen et al. 2004) but the decline remains unexplained.

Central and northern Alberta, which formerly provided a large amount of wetland habitat for the Horned Grebe, continues to undergo rapid development due to agriculture, urbanization, forestry and the energy sector, which promises to have severe impacts on this and other wetland-associated species. Interestingly, although development generally results in the destruction of natural wetland habitat, construction (especially of roads) results in the creation of borrow-pits which fill with water and can function as artificial ponds. Although there are many types of constructed wetlands, such as agricultural dugouts and ponds for storm water runoff which may incidentally create habitat for waterfowl, waterbirds and shorebirds, my research focuses on borrow-pits.

Constructed wetlands as habitat

Several studies have considered constructed ponds as potential habitat for aquatic birds. Kertell and Howard (1997) found that constructed impoundments associated with oil fields in Alaska can be as suitable as natural ponds for invertebrate-eating waterbirds. It has also been found that Pacific Loons (*Gavia pacifica*) reproduce as successfully on these impoundments as on natural ponds (Kertell 1996). Constructed wetlands in Virginia have equal species richness, diversity and abundance as nearby natural, reference wetlands (Balcombe et al. 2005). In addition, borrow-pits in Florida provide vital nesting habitat for wading birds, including the endangered Wood Stork (*Mycteria americana*; Bryan et al. 2003). Fournier and Hines (1999), of the Canadian Wildlife Service (CWS) observed a high incidence of Horned Grebes nesting on borrow-pit and natural roadside ponds in the Northwest Territories. More recent surveys conducted by CWS (air and ground) in the Peace Parkland of northwestern Alberta indicate that Horned Grebes nest on borrow-pits as frequently as they nest on natural wetlands. Occurrence of grebes on ponds in this area appears to be high compared to other areas in Alberta (Gingras and Beyersbergen 2003), possibly due to a lower density of human occupation and lower levels of disturbance to associated uplands than in more southern areas of Alberta. The majority of the borrow-pits in the Peace Parkland were constructed when the highways were either paved or twinned, in the late 1960s and early 1970s (T. McLaughlin, Alberta Transportation, personal communication).

Study area

The Peace Parkland of northwestern Alberta is a unique and diverse landscape, a transition zone between the boreal forest and grasslands that have largely been converted to agriculture. This region is used as breeding and staging area by thousands of birds each year (Beyersbergen et al. 2004). However, relatively little ecological research has been conducted in the Peace country, particularly on borrow-pits. Field work for my study was conducted at constructed and natural ponds located along highways from High Prairie, to north of High Level, Alberta.

Thesis goals and outline

The central goal of my study is to gain a better understanding of the use of constructed ponds as breeding habitat by Horned Grebes and other aquatic birds in Alberta and therefore determine whether constructed ponds benefit populations of aquatic birds. In Chapter 2, I examine Horned Grebe habitat selection through surveys of constructed and natural ponds, examining the physical and chemical characteristics of ponds, their surrounding land-cover, and invertebrate resources, to identify environmental differences between ponds occupied and ponds unoccupied by Horned Grebe adults and chicks. In Chapter 3, I further address the question of why some ponds are selected as breeding habitat while others are not through examining the food-webs of occupied and unoccupied ponds with stable isotope analysis, as differences in trophic structure may be indicative of important habitat differences (O'Donnel and Fjeldså 1997). In Chapter 4, I examine bird assemblages occupying constructed ponds across the breeding season, to determine which species besides Horned Grebes use borrow-pits as habitat and whether there are certain bird assemblages characteristic of ponds with different habitat features. Chapter 5 discusses the main results and conclusions of my study as well as offering management reccomendations.

As development in Alberta currently shows no sign of slowing, and natural wetlands continue to disappear or are being degraded, the role of constructed wetlands in avian conservation deserves consideration. My study will contribute to conservation efforts for Horned Grebes and other aquatic birds in the Peace Parkland and the boreal forest–agriculture transition zone of northwestern Alberta, an important breeding area for waterfowl, grebes, and shorebirds. It is possible that identifying ponds that are good for grebes will identify ponds that serve as good habitat for other aquatic birds. Similarly, understanding what features make these ponds good grebe habitat (e.g., landscape characteristics, local pond features and food resources) will likely point to features that result in good habitat for other birds.

Literature cited

Balcombe C. K., J. T. Anderson, R. H. Fortney, and W. S. Kordek. 2005. Wildlife use of mitigation and reference wetlands in West Virginia. Ecological Engineering **25**:85-99.

Bernstein C., J. R. Krebs, and A. Kacelnik. 1991. Distribution of birds amongst habitats: theory and relevance to conservation. *In* Bird population studies, Oxford University Press, New York.

Beyersbergen G. W., N. D. Niemuth, and M. R. Norton. 2004. Northern Prairie and Parkland Waterbird Conservation Plan. A plan associated with the waterbird conservation for the Americas initiative. Denver, Colorado: Prairie Pothole Joint Venture. 183pp.

Bryan J. C., S. J. Miller, C. S. Yates, and M. Minno. 2003. Variation in size and location of wading bird colonies in the upper St. Johns river basin, Florida, USA. Waterbirds **26**:239-251.

Cody M. L. 1981. Habitat selection in birds: the roles of vegetation structure, competitors, and productivity. Bioscience **31**:107-113.

Downes C. M., and B. T. Collins. 2008. Canadian Bird Trends Web site Version 2.2. Canadian Wildlife Service, Environment Canada, Gatineau, Quebec, K1A 0H3.

Fisher C., and J. Acorn. 1998. Birds of Alberta. Lone Pine Publishing, Winnipeg, Manitoba, Canada. 384pp.

Fjeldså J. 1973a. Distribution and geographical variation of the Horned Grebe *Podiceps auritus* (Linnaeus, 1758). Ornis Scand. **4**:55-86.

Fjeldså J. 1973b. Feeding and habitat selection of the Horned Grebe, *Podiceps auritus* (Aves), in the breeding season. Vidensk Medd Dan Naturhist Foren **136**:57-95.

Fournier M. A., and J. E. Hines. 1999. Breeding ecology of the Horned Grebe (*Podiceps auritus*) in subarctic wetlands. Canadian Wildlife Service; Occasional paper 99.

Fretwell S. D. 1972. Populations in a seasonal environment. Princeton University Press, Princeton.

Fretwell S. D., and H. L. Lucas Jr. 1970. On territorial behavior and other factors influencing habitat distribution in birds I. Theoretical development. Acta Biotheoretica **19**:16-36.

Gingras B. A., and G. W. Beyersbergen. 2003. Horned Grebe use of artificial ponds in forested and agricultural areas of northwestern Alberta. Poster presentation: Society of Canadian Ornithologists.

Kertell K. 1996. Response of Pacific loons (*Gavia pacifica*) to impoundments at Prudhoe Bay, Alaska. Arctic **49**:356.

Kertell K., and R. L. Howard. 1997. Impoundment productivity in the Prudhoe Bay oil field, Alaska: Implications for waterbirds. Environmental Management **21**:779-792.

O'Donnel C., and J. Fjeldså. 1997. Grebes - status survey and conservation action plan. IUCN/SSC Grebe Specialist Group. Gland, Switzerland and Cambridge, UK: IUCN; vii + 59 pp.

Rosenzweig M. L. 1991. Habitat selection and population interactions: the search for mechanism. The American Naturalist **137**:S5-S28.

Stedman, S. J. 2000. Horned Grebe (*Podiceps auritus*). The birds of North America online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the birds of North America online: http://bna.birds.cornell.edu/bna/species/505, DOI:10.2173/bna.505.

Svardson G. 1949. Competition and habitat selection in birds. Oikos **1**:157-174.

Vlug J. J., and J. Fjeldså. 1990. Working bibliography of the grebes of the world, with summaries of current taxonomy and distributional status. University of Copenhagen in association with ICBP and IWRB. Technical Publication, Zoological Museum, Copenhagen, Denmark.

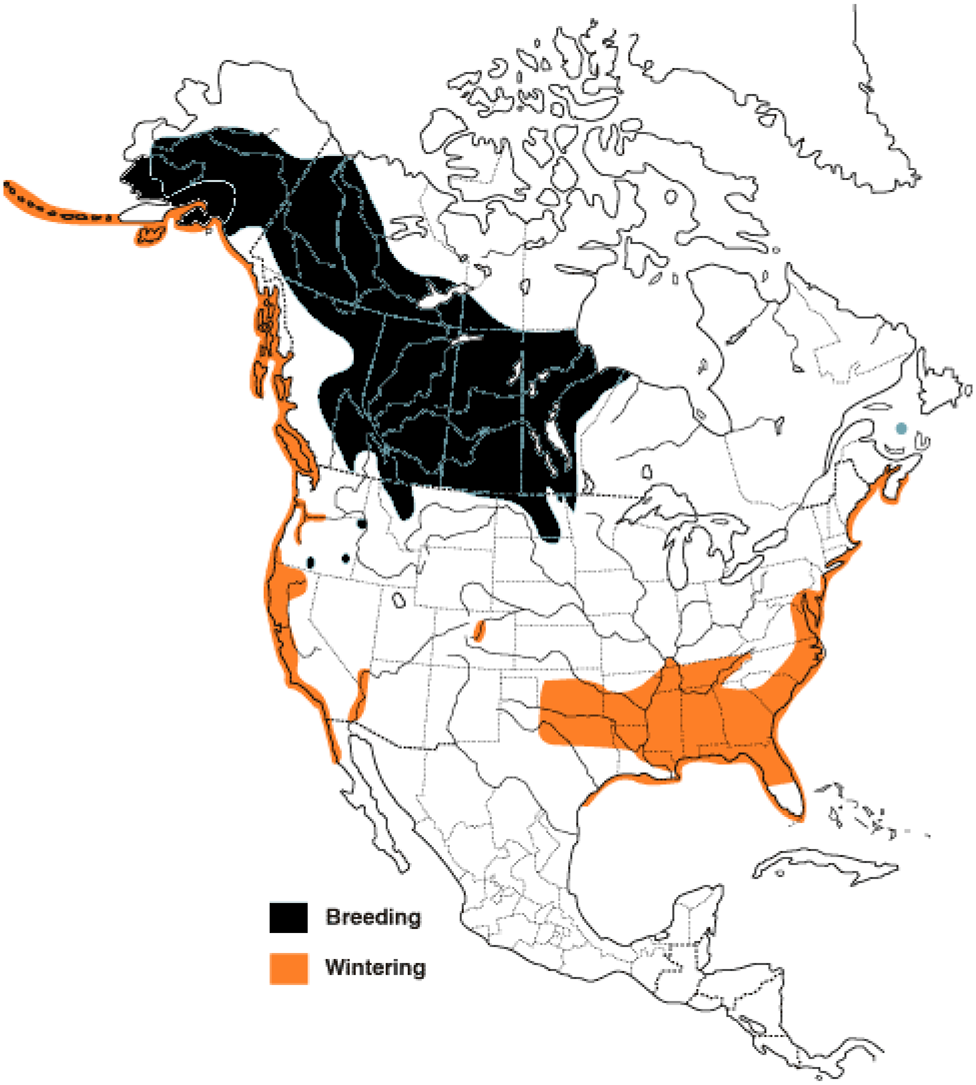


Figure 1.1: Distribution map of the Horned Grebe in North America (Distribution map provided by http://bna.birds.cornell.edu and the Cornell Lab of Ornithology).

Chapter 2

Habitat selection of the Horned Grebe (*Podiceps auritus*) on constructed wetlands in the Peace Parkland

Introduction

Wetlands are constructed by various processes, either deliberately or incidentally. They are often created as part of mitigation programs in which new wetlands replace natural wetlands that have been destroyed for various reasons. Alternatively, wetlands are created to provide specific services, such as storm water recharge or nutrient retention in waste water treatment systems. Borrow-pits are ponds that are created incidentally during routine construction operations when soil is removed ('borrowed', with intention to eventually return it) from locations along highways, in order to build up the road bed. However they are created, constructed wetlands differ from natural sites in fundamental ways; it can be very difficult to mimic natural conditions in constructed wetlands (Wetzel 2001). Differences between natural and constructed wetlands are well documented (Zampella and Laidig 2003, Hoeltje and Cole 2008).

Natural wetlands are habitat for many different species of waterbirds, thus these species suffer when wetlands are destroyed by agriculture, industry and urbanization (Mitsch and Gosselink 2000). Particularly in western Canada, habitat loss due to agricultural expansion is responsible for declines of a number of species of breeding waterfowl, such as Mallard (*Anas platyrhynchos*) and

Northern Pintail (*Anas acuta*; Bethke and Nudds 1995). Constructed wetlands may provide habitat, for at least some bird species. For instance, Maillet et al. (1999) found that waterbird productivity remained constant or increased on constructed impoundments in eastern Canada as impoundments aged, rather than declining as anticipated. My study evaluates borrow-pit ponds as summer habitat for a single waterbird species, Horned Grebe (*Podiceps auritus*), in northwestern Alberta, Canada.

The Horned Grebe is non-game diving waterbird found in Eurasia and North America. The morphology of grebes is such that their legs are placed far back on their bodies, which suits them well for diving, but severely limits bird movement on land. The Horned Grebe is totally dependent on aquatic habitat year-round, even nesting over the water's surface (Stedman 2000). Because of this dependence, the Horned Grebe may serve as a useful indicator of the quality of wetland habitat (O'Donnel and Fjeldså 1997).

Horned Grebe populations are declining, they are now listed as a species "of high concern" by the Northern Prairie and Parkland Waterbird Conservation Plan (Beyersbergen et al. 2004); reasons for the decline are unknown but it is most likely associated with the destruction of native wetland habitat. Despite this decline, the Horned Grebe appears to be benefiting from constructed wetlands. Fournier and Hines (1999) surveyed natural and constructed borrow-pit ponds near Yellowknife, Northwest Territories from 1986 to 1996 and found higher use by Horned Grebes of constructed versus natural wetlands of similar sizes. Gingras and Beyersbergen (2003) recorded 36% occupancy by the species on borrow-pit ponds in the Peace Parkland, northwest Alberta in 2003. Horned Grebes seem to select borrow-pits as potential breeding sites in prairie and parkland Alberta, Saskatchewan and Manitoba greater than the relative availability of the ponds on the landscape (Caldwell, unpublished report). Horned Grebes may in fact cluster in certain areas, but the causes of these patterns are unknown (Caldwell, unpublished report).

In this study I investigated the construction of borrow-pit wetlands as a conservation strategy for Horned Grebes in Alberta. I examined the use and habitat selection of borrow-pits in the Peace Parkland by adult Horned Grebes, through conducting multiple surveys in 2007 and 2008, to document seasonal patterns of occurrence, and compare recent patterns to survey data collected in May 2003 by Gingras and Beyersbergen (2003) that initially documented the prevalence of this species in the region. I use the term “habitat selection” to describe the phenomenon of a bird choosing a pond on which to forage or breed, based on various parameters, over other available sites. I documented occurrence of adult Horned Grebes and chick production, biotic habitat features, such as vegetative coverage, and invertebrate food resources, as well as landscape, and physical and chemical characteristics associated with occupied and unoccupied borrow-pits in the Peace Parkland.

The goal of my project was to characterize borrow-pits as habitat for Horned Grebes by investigating how ponds occupied by grebes differ from ponds unoccupied by grebes. Although Horned Grebes are relatively abundant in the Peace Parkland, they do not occur on all ponds. In addition, I made a limited comparison of grebe occurrence on, and features, of small natural wetlands in the region. I asked the following questions: 1) What is the frequency of occurrence of Horned Grebes on constructed ponds in the Peace Parkland? 2) What local features of individual ponds and larger features of the surrounding landscape are related to the occurrence of Horned Grebes? 3) What is the level of chick production on borrow-pits, and what habitat features determine which ponds with grebes produce chicks? 4) Are there differences in grebe occurrence or success between ponds in agricultural versus forested landscapes? 5) What are the environmental characteristics of small natural wetlands in the Peace Parkland, and how does Horned Grebe occurrence and chick production on borrow-pits compare to natural wetlands?

I made the following predictions. I expected that Horned Grebes would be found on ponds that are farther from roads (a potential source of disturbance), and support an abundance of peripheral emergent vegetation for nest construction and shelter. I predicted pond area to be important; Horned Grebes are territorial and tend to occupy relatively small natural wetlands (Stedman 2000). However, there should be a lower size limit to ponds capable of supporting breeding grebes. All borrow-pits in the Peace Parkland are fairly small (< 2.61 ha); because of this I predicted that Horned Grebes will occur, and produce broods, on larger borrow-pits. I also expected Horned Grebes to occur on ponds exhibiting higher levels of primary production than unoccupied ponds and consequently invertebrate food resources to be more abundant in ponds with grebes. Previous studies (e.g. Dwyer 1970, Beyersbergen and Gingras, unpublished data) have documented differences in occurrence of grebes among ponds in agricultural versus forested land-cover types. I predicted Horned Grebe occurrence would be more frequent on constructed ponds in agricultural areas. Horned Grebes in Europe are attracted to eutrophic waterbodies (Fjeldså 1973); agricultural ponds may be more productive due to increased nutrient runoff from uplands, or to association with better quality soils, compared to forested ponds. There are few data available on natural wetlands in the Peace Parkland, however, I predicted grebes to be found on small natural wetlands with an abundance of peripheral emergent vegetation and an open water interior, most similar to typical prairie potholes (van der Valk 2006) that provide important habitat for this species in the southern extent of its range (Stedman 2000).

Methods

Surveys

Table 2.1 presents a summary of dates and number of ponds visited during each survey as well as the other types of field data collected in 2003 by Gingras and Beyersbergen (2003), and by myself in 2007 and 2008.

In May 2003 Gingras and Beyersbergen of the Canadian Wildlife Service (CWS) surveyed 340 constructed borrow-pit ponds between the towns of High Prairie to north of High Level, Alberta (from 55.43 N, -116.76 W to 58.98 N, -117.63 W). They recorded all waterbirds on ponds between 0700 and 1600, and made noise to flush secretive birds. They also made a rapid habitat assessment, by recording the percent of peripheral emergent and riparian vegetation surrounding each pond, as well as the occurrence of beaver (*Castor canadensis*) activity, and took notes on human structures within the pond, such as a bubbler or pump (Gingras and Beyersbergen 2003, Gingras and Beyersbergen, unpublished data). In May 2007 I located 330 of the ponds previously surveyed by Gingras and Beyersbergen (2003; Figure 2.1a). Eight small roadside natural wetlands were also located along survey routes as references for comparison with constructed sites. My surveys were conducted between 0700 and 1700. If the pond surface was visible from the roadside, two observers first stood on the edge of the road and took note of all birds on the pond to reduce the chance of missing birds that flushed quickly. Then each observer walked to the edge of the pond at different points to record birds, thus decreasing the chance of missing birds not visible to one observer from one point. These scans lasted an average of five minutes. Noise was then made (i.e. hand clapping) to flush secretive birds before departing from ponds. Ponds were on average 38 m from the road, located along two-lane highways that varied in their level of vehicular traffic.

After the initial May 2007 survey, 100 ponds on which grebes had been present and 100 ponds on which grebes had been absent were selected, maintaining a balance between ponds in agricultural versus forested areas. One additional pond that had not been surveyed in May 2007, but had grebes present in June 2007, was used for stable isotope analysis (Chapter 3) and therefore included in all subsequent surveys; data from this additional pond were included in analyses that do not include May survey results. These 201 constructed and eight natural ponds (total 209 ponds; Figure 2.1b) were surveyed again in June, July and August 2007. In July and August the number of Horned Grebe chicks on each pond was recorded. The same 209 ponds which were surveyed in 2007 were visited again in June and August 2008, as well as an additional 10 natural wetlands, totaling 201 constructed ponds and 18 natural wetlands for 2008 (Table 2.1). Number of monthly visits was reduced in 2008 as it was determined in 2007 that a June survey provided the best record of breeding pairs of grebes, while an August survey recorded chick production.

Local habitat and limnological data

The proportions of emergent vegetation (generally *Typha latifolia* but occasionally *Carex* or *Juncus* spp.) and riparian vegetation (trees and shrubs, typically *Populus or Salix* spp.) surrounding the perimeter of each pond were estimated visually in August 2007. The proportion of total pond area covered by emergent vegetation (a measure of the width of the zone of emergent vegetation) versus open water was also recorded. Coverage estimates were measured in 5% increments, (e.g. 0%, 5%, 95%) and confirmed by two observers. Emergent and riparian vegetation could potentially be important to Horned Grebes as material for nest construction and anchorage, as well as providing shelter (Stedman 2000). The Bayley and Prather (2003) index of submersed aquatic vegetation (SAV) was recorded at each pond in July 2007 and June 2008, based on ranking the proportion of the pond covered by SAV (visible below the water's surface) as a score, 1-5, with 1: 0%, 2: < 5%, 3: 5-25%, 4: 25-75% and 5: > 75%. SAV can be indicative of primary production within lakes, and can be used to determine whether ponds undergo "alternative stable states", involving a clear-water, SAV-dominated state and a turbid-water, phytoplankton-dominated state (Scheffer et al.

1993, Bayley and Prather 2003). Primary productivity is linked to invertebrate abundance; high SAV coverage and resulting habitat complexity may also be related to the density and richness of macroinvertebrates (Jeppesen et al. 1998).

Pond area, and the distance from the edge of the road to the edge of the pond were calculated using a Bushnell Yardage Pro® rangefinder. Although all borrow-pits were along roadsides, the distance from the road may affect a grebe's decision when selecting a pond. Roads are a potential source of disturbance for grebes, both through noise and dust. Any evidence of beaver activity was also recorded for each pond (as either present or absent), as beavers have been found to influence wetland use by waterbirds (reviewed in Rosell et al. 2005). This included presence of a lodge, downed trees with beaver markings, or sighting the animals themselves. Beaver activity was present at 34 (out of 200) ponds in 2003 and 62 ponds in 2007 and 2008. I also recorded whether there was evidence of human disturbance within ponds (as present or absent); this included presence of a bubbler (possibly evidence of fish stocking), pump, or dock. Human disturbance was present in 10 ponds.

Water was sampled from 29 constructed ponds in July 2007 and 52 ponds in June 2008 (46 constructed, 6 natural) for total nitrogen (TN), total phosphorus (TP) and chlorophyll-a. Ponds were distributed throughout the study area, maintaining a balance between Horned Grebe presence/absence and ponds surrounded by agriculture versus forest. Pond water was filtered on-site for chlorophyll-a; filters were frozen prior to processing. TN, TP and chlorophyll-a were analyzed at the Biogeochemical Analytical Laboratory at the University of

Alberta. pH and conductivity were measured using hand-held meters in both years. pH was measured with a waterproof pHTestr 10 and conductivity was measured with an EC Testr low (0 to 1990 µS). I recorded the mean of two readings taken per pond just below the water's surface. Mean pH values presented in tables were calculated based on back-transformed data. In July 2007 maximum depth and Secchi depth (for 20 out of 29 ponds not visible to bottom) were measured from the center of each pond.

Landscape analysis

I conducted landscape analyses in ArcGis 9.2 (ESRI 2007) to characterize land-cover surrounding borrow-pits and natural wetlands in the study area. In addition to within-pond characteristics (described earlier), there is evidence that landscape characteristics can be important in habitat selection of aquatic birds (Dwyer 1970, Saab 1999). I measured the amount of, and distance to, water on the landscape surrounding ponds, to determine the general connectivity of borrow-pits to other sources of water on the landscape. Wetland connectivity can be very important to some species of aquatic birds (Haig et al. 1998) because they commonly use multiple wetlands during a breeding season. Scanned aerial photographs from 1997 and 2001 (High Level area) and 1999 (south of High Level) were obtained from the Alberta Government and georeferenced to ponds. Images from Google Earth (Google Earth 4.2.0205.5730) were used when air photos were not available. A 1 km buffer was created around delineated ponds and dissolved to remove overlapping polygons. Mensing et al. (1998) found that birds responded to 500 m and 1 km landscape scales associated with wetlands in

Minnesota; I chose to use a 1 km buffer to capture a greater area of the landscape surrounding ponds. Land-cover types were delineated within the dissolved buffer according to the following categories: forest, agriculture (including both pasture and crop), water (subdivided into natural and constructed), road, homestead, industry, forestry cut block, and other (cover types that do not fall into the above categories, such as ditches). Proportions of different land-cover categories within the buffer were calculated; the distribution of these eight land-cover categories across the 201 borrow-pits and 18 natural wetlands is summarized in Appendix 2.1. Appendix 2.2 presents the division of proportion of water within the 1 km buffer into water from constructed versus natural sources for the 201 borrow-pits and 18 natural wetlands. The only land-cover categories used in analyses were the proportions of water (pooled natural and constructed sources) and forest within 1 km; proportion forest was used as a surrogate for agriculture, as agriculture and forest within 1 km were highly correlated (Spearman's rho = -0.962, $p < 0.001$). Forest was chosen for use in analyses, instead of agriculture, as all ponds had some forest within 1 km but some ponds had no agriculture within their buffers. The straight-line distance from the edge of each pond to the edge of the nearest water body (regardless of origin) was also measured.

Fish occurrence and sampling of invertebrate biomass

I checked for the presence of fish in the 29 ponds sampled for water chemistry in 2007 by leaving four Gee minnow traps overnight in each pond.

In July 2007 I conducted a total of six sweeps for aquatic invertebrates with a standard D-frame invertebrate dip net at each pond, modified from

Hornung and Foote (2006). One inshore (within the zone of emergent vegetation) and one offshore (outside of the zone of emergent vegetation, in the open water zone) upwards, vertical sweep was performed in each of three separate locations per pond, along the shore closest to the road for consistency. An average of 7126 cm^3 water volume was sampled at inshore locations (water depth: $\overline{x} \pm$ SE: 25.54 ± 1.67 cm) and 19953 cm^3 was sampled at offshore sampling locations (water depth: 71.52 ± 3.76 cm). Samples were picked free of vegetation, filtered of pond water and preserved in ethanol. Invertebrates were identified to Order or Suborder and oven dried for seven days. Dried invertebrates were then weighed using an analytical balance accurate to 0.01mg. Taxa within the inshore and offshore sweeps were pooled such that organisms from each Order or each Suborder were combined (e.g. one weight for Amphipoda from each inshore and offshore sweep from each pond). Taxa with few or very small individuals were combined, although they were still separated into inshore versus offshore samples.

Statistical analysis

Analyses were carried out using SPSS 16.0 and 17.0 for Windows (SPSS Inc. Chicago, IL USA) unless otherwise stated. When multiple comparisons were necessary for non-parametric tests I used the Bonferroni correction to calculate a new α (new α = 0.05/number of comparisons; Gotelli and Ellison 2004). Abbreviations for environmental variables used in analyses are summarized in Table 2.2.

Detectability

Although I conducted multiple surveys at each site for Horned Grebes in 2007 and 2008 I did not adjust counts for detectability rates. I believe that detectability is fairly high for borrow-pits in Alberta, as ponds are small and Horned Grebes are fairly conspicuous. Borrow-pits are not closed systems (a requirement for calculation and analysis of detection probability; MacKenzie 2005). Use of ponds in May was higher than other months due to the presence of migrating birds. Not all birds that use borrow-pits early in the season stay and breed, likewise failed nesters may move among ponds, attempt to re-nest, or leave the area all together.

Occurrence of Horned Grebes on constructed wetlands

I conducted McNemar and Cochran's tests to compare occurrence of Horned Grebes (presence/absence) among survey months, across survey years. These tests are the equivalent of a paired *t*-test and repeated measures ANOVA, respectively, for ordinal data.

Fish occurrence and invertebrate biomass

Inshore and offshore invertebrate biomass within each pond was compared with a paired *t*-test. As these did not differ, inshore and offshore biomass were pooled and total biomass was compared between ponds with (n = 17) and without (n = 12) grebes in 2007 using an independent samples *t*-test. Two invertebrate taxa suspected to be important for grebes were analyzed individually; I analyzed total biomass of Odonata and Coleoptera between ponds with and without grebes with independent samples *t*-tests. As the presence of fish can impact invertebrates in ponds (Hornung and Foote 2006), I compared invertebrate biomass between ponds with (n = 5) and without (n = 24) fish with an independent-samples *t*-test.

Multivariate analysis of Horned Grebe habitat selection

To determine which local and landscape habitat features measured for all 200 ponds influenced grebe occurrence over the three years (2003, 2007, 2008), I conducted generalized linear mixed model (GLMM) regressions with binomial error structure and a logit link using glmmML (written by Göran Broström, Umeå University, Sweden) in R, version 2.8.1 (R Project for Statistical Computing, http://www.r-project.org). The glmmML package has advantages over other GLMM packages as it uses the maximum likelihood approach to fit models, allowing for the use of information theoretic approaches for model selection (see below). Adult grebes were considered present on a pond in a given year if birds were observed in one or more surveys. Thus, for the 200 ponds sampled in all three years, presence was based on one survey in 2003 (in May), four monthly surveys in 2007 (May – August), and two surveys in 2008 (June and August). Grebe presence/absence data had been collected in an unmatched case-control design (Keating and Cherry 2004), as I had controlled the proportions of occupied and unoccupied sites surveyed (initially 100 occupied and 100 unoccupied in May 2007) and thus grebe occurrences observed were not indicative of the proportion of occupied ponds on the landscape. This allows for interpretation of grebe habitat use/non-use in terms of odds ratios (Keating and Cherry 2004). Unique pond identity number was included in analyses as a cluster variable (random effect) to account for repeated measurements on the same ponds across three years; all other variables were included as fixed effects. Environmental variables were screened prior to analysis with a correlation matrix; one of each pair of correlated variables having r > 0.7 was eliminated prior to further analysis.

I used an information-theoretic approach to model selection (Burnham and Anderson 2002). I constructed 10 models based on a priori hypotheses (Table 2.3), each with a different 'theme', in an attempt to separate local and landscape habitat features, encompass the predictions made by Gingras and Beyersbergen (2003), and assess the importance of water on the landscape, vegetation patterns, and human influence on patterns of grebe occurrence. This set of models will be hereafter referred to as "coarse environmental" models as the parameters used in these analyses were measured during regular surveys for all 200 ponds (with the exception of land-cover data generated from air-photos in GIS). Models consisted of (1) a global model with all variables, in the event that all variables in combination are important in describing grebe occurrence and (2) an area-only model in the event that only pond size affected use. I created three models describing the vegetation surrounding ponds to determine the importance of vegetation at different spatial scales: (3) all vegetation, (4) local vegetation only, and (5) landscape vegetation only. I also created (6) a 'landscape variables' model, as local pond features might have nothing to do with occurrence by grebes and only geographic location matters, and (7) a model with all parameters measured at a local pond scale. I created a model with (8) parameters associated with water on the landscape ('water variables'). Another model included (9) a combination of variables (area, forest within 1 km, emergent vegetation and beaver) to encompass the features thought to be important by Gingras and Beyersbergen (2003) following a rapid habitat assessment made during their survey for Horned Grebes in May 2003. Finally, as borrow-pits may be subject to direct disturbance by humans, I created a model that contained (10) the presence of human disturbance and distance from the road. “Year of survey” was included in each model in order to capture inter-annual variation unexplained by the model parameters.

I used Akaike’s Information Criterion for small sample sizes (AIC_c) to rank competing models. AIC can be thought of a measure of ‘badness of fit’, an indication of the relative distance of a model from an approximation of ‘the truth’ (Burnham and Anderson 2002). The model with the smallest AIC_c thus has the best support given the data. All other models are compared to the model with the smallest AIC_c using Δi (the AIC_c of the ‘best’ model subtracted from the AIC_c of each competing model); as a general rule, models with $\Delta i < 2$ are considered equivalent at describing the phenomenon of interest and Δi from 3-7 have much less support (Burnham and Anderson 2002). Akaike weights (w_i) were used to determine the probability that the model with the smallest AIC_c was actually the best; the closer w_i is to 1, the better the model (Burnham and Anderson 2002).

I performed Kolmogorov-Smirnov tests to compare the distributions of ponds with and without Horned Grebes across variables that had significant odds ratios, (and therefore odds ratios and confidence intervals did not include 1).

As SAV could not be included in the GLMM (due to multicollinearity problems and thus potentially led to incorrect parameter estimates; Gotelli and

Ellison 2004) but still might be an important factor determining Horned Grebe occurrence (Cramp and Simmons 1977), I conducted independent samples *t*-tests comparing SAV from 2007 and 2008 for ponds occupied and unoccupied by grebes.

Limnology of constructed wetlands

Limnological parameters were log (x+1) transformed prior to analysis with the exception of pH (already on a log scale) and conductivity (already normally distributed and unimproved with transformation). Parameters sampled from the same 26 ponds in 2007 and 2008 were compared with paired *t*-test to determine whether they varied between years.

A new set of models was constructed that added water chemistry and other variables having significant odds ratios in the coarse environmental GLMM analyses, in an attempt to separate and compare between abiotic, biotic, morphometry, local pond and landscape models in predicting presence of adult grebes ("coarse + chemistry" models; Table 2.4). It was not possible to include the variable human disturbance in models as no evidence of human disturbance was present in the 46 ponds sampled for chemistry. In addition to (1) the global model with all variables, I constructed a (2) 'biotic' model, including all parameters related to living organisms. I also evaluated a model encompassing (3) all abiotic parameters in the candidate set of models as well as (4) a model only considering parameters associated with pond water chemistry (TP, pH, and conductivity). I included a model that encompassed (5) 'water-related' parameters (water chemistry parameters plus chlorophyll-a) as well as (6) a 'landscape' model (with proportion forest) to attempt to distinguish the importance of local pond versus this landscape characteristic when compared to the candidate set. A final model consisted of (7) parameters associated with pond morphometry (Table 2.4). The analyses were run using the glmmML package; pond identity was included as a random effect and year was included as a fixed effect. The models included only 2007 and 2008 presence/absence data, as although 2007 and 2008 water chemistry was fairly consistent I had no way of assessing values from 2003. Models were ranked according to AIC_c. As there was no one 'best' model with a low AIC_c or a high w_i, (w_i were all < 0.5), I employed model averaging, where estimated coefficients are multiplied by w_i for the subset of models containing the parameter of interest and summed across all models (Burnham and Anderson 2002). I also calculated the unconditional standard error for each model-averaged coefficient (Burnham and Anderson 2002, Johnson and Omland 2004).

To follow up on significant parameters from this analysis I conducted *t*-tests (on transformed limnological parameters), and Wilcoxon signed-rank tests (on environmental data) to compare ponds with and without beaver activity, the only significant parameter following model averaging.

Horned Grebe chick production on borrow-pits

To determine if chicks were produced on the same ponds in both study years, I compared presence/absence of chicks on 201 ponds from 2007 to 2008 with McNemar tests. I also compared the maximum number of chicks observed per pond between 2007 and 2008 with Wilcoxon Signed rank tests to determine if ponds performed consistently between the two years. Maximum number of chicks was used to account for low numbers within a survey potentially due to late hatching broods or early migrants in August; this method was also used by Fournier and Hines (1999).

I conducted additional logistic regression analyses using glm in R with binomial error and logit link to examine chick production on ponds where adult grebes had been present for each year. Here, 0 = adults present but no chicks produced, 1 = adults present and chicks produced. As different ponds were occupied in 2007 and 2008, I conducted a separate set of analyses for each year. Although I intended to use the same 10 models used for the coarse environmental GLMM analyses, slight modifications to these models were necessary. The proportion of pond area covered by emergent vegetation ("areaemerg") was not used in the coarse environmental GLMM as it had not been recorded in 2003, but was included in some glm models as these only involved data from 2007 and 2008. For successful chick production, the width of the emergent zone might be important, and not simply coverage of the periphery of the pond (measured by "emerg"). Wider zones of vegetative coverage may provide additional shelter from predators (for both the nest and chicks). In addition, the variable human (human disturbance) had to be removed from models as it was not present on a sufficient number of ponds for further analysis. Models used to evaluate chick production (hereafter termed "coarse + chicks" models) are summarized in Table 2.5. Models were ranked according to AIC_c and model averaging was employed.

Agricultural versus forested ponds

To further explore the factors affecting the suitability of ponds as Horned Grebe breeding habitat between predominant land-cover types, I compared the maximum number of chicks per pond (for all ponds that produced one or more chicks based on the 201 pond group) in each year between agricultural (<49.9% forest within 1 km of pond) and forested ponds (>50% forest) using Mann-Whitney U tests. I also compared total invertebrate biomass between agricultural and forested ponds using an independent samples *t*-test, and I conducted additional *t*-tests to compare the transformed limnological parameters (TN, TP, chlorophyll-a, pH, and conductivity) between agricultural and forested ponds to determine if these pond types differed in water chemistry.

Natural wetlands

To fully assess constructed ponds as habitat for Horned Grebes, I surveyed eight natural wetlands in 2007 and 18 in 2008 to use as reference sites. I conducted McNemar and Cochran's tests to compare occurrence of Horned Grebes (presence/absence) on natural ponds among survey months across survey years. I compared occurrence of chicks on natural ponds sampled in both 2007 and 2008 with McNemar tests. I compared the maximum number of chicks per pond observed in 2007 and 2008 with Wilcoxon Signed rank tests. Limnological parameters measured in natural (n = 6) and constructed (n = 46) ponds were compared with independent samples *t*-tests.

Results

Occurrence of Horned Grebes on constructed ponds

In May 2003 Gingras and Beyersbergen (2003) surveyed 340 ponds in the Peace Parkland and observed Horned Grebes on 123 (36%). I also observed 36% occurrence of grebes on 330 of these ponds in 2007 (Table 2.5a). This indicates that Horned Grebes may be repeatedly using the same ponds. Indeed, Horned Grebes were occurring on many of the same constructed ponds in May 2003 and May 2007 (n = 330 ponds, McNemar test: $\chi^2 \leq 0.0001$, $p = 1.00$). Sixty-five out of the 330 borrow-pits were occupied by grebes in both years (19.7% of all ponds), and 154 lacked grebes in both years (46.7% of ponds). However Horned Grebes were not using the same ponds when I compared the smaller subset of 200 ponds sampled in all three years for 2003, 2007 and 2008 (Cochran's $Q = 27.44$, df = 2, $p < 0.001$). Thirty-three out of 200 (16.5%) ponds were occupied in all three years, 60/200 (30.0%) remained unoccupied in all three years, 57/200 (28.5%) were occupied in two out of three years and 51/200 (25.5%) were only occupied in one year. Horned Grebes were using the same ponds when only comparing 2007 and 2008 data (McNemar test: $\chi^2 \leq 2.72$, $p = 0.099$); 92/201 (45.8%) ponds were occupied by grebes both years, 56/201 (27.9%) ponds remained unoccupied and 53/201 (26.4%) were occupied in one of the two years.

Table 2.6a summarizes Horned Grebe adult and chick occurrence and abundance on constructed ponds in May 2003, May through August 2007, and June and August 2008. Occurrence of adult grebes on constructed ponds differed across the four months of sampling in 2007 (Cochran's test based on Horned Grebe presence/absence: n = 200, $Q = 151.04$, df = 3, $p < 0.001$; Figure 2.2a).

After applying a Bonferroni correction ($\alpha = 0.008$), occurrence in May was higher than in July (McNemar test: n = 201, $\chi^2 = 12.57$, $p < 0.001$), and occurrence in July was higher than in August (n = 201, $\chi^2 = 63.01$, $p < 0.001$), however occurrence did not differ between May and June (n = 200, $\chi^2 = 4.89$, $p = 0.027$) or between June and July (n = 201, $\chi^2 = 2.94$, p 0.086; Fig. 2.2a). Occurrence of chicks did not differ between July and August 2007 (n = 201, $p = 0.108$ using the binomial distribution; Figure 2.2a). Occurrence of both adults and chicks differed between June and August 2008 (Figure 2.2b). Occurrence of adults was higher in June (McNemar test: n = 201, $\chi^2 = 74.30$, $p < 0.001$), and occurrence of chicks was higher in August (n = 201, $\chi^2 = 39.41$, $p < 0.001$; Figure 2.2b). Most ponds in both years supported one pair of grebes. However in May 2007 three ponds supported three adult grebes and one supported four grebes. In June there was one pond that supported four grebes and in July there was one pond with three adult grebes and one pond with four. Only one pond consistently had two pairs from month to month. In June 2008 there was one pond with three adult grebes and one pond with four.

Fish and invertebrates in relation to grebe occurrence

I checked for the presence of fish in a subset of 29 ponds in 2007. Fish were found in five ponds. Of these, four contained brook stickleback (*Culaea inconstans*) and one of these also contained northern redbelly dace (*Phoxinus eos*). One additional pond was stocked with rainbow trout (*Oncorhynchus mykiss*) and also contained pearl dace (*Margariscus margarita*). Horned Grebes occurred on three ponds with fish. There was no difference in invertebrate biomass between ponds with (n = 5, $\bar{x} \pm$ SE: 126.04 ± 54.41 mg) and without (n = 24, 115.15 ± 23.82 mg) fish ($t_{27} = -0.19$, $p = 0.85$).

There was no difference between mean total biomass of invertebrates from sweeps taken inshore (range: 3.64 - 238.39, $\bar{x} \pm$ SE: 51.77 ± 9.20 mg) and offshore (range: 4.93 - 337.42, $\bar{x} \pm$ SE: 65.36 ± 15.49 mg; paired *t*-test: $t_{28} = -0.98$, $p = 0.34$). Biomass of inshore and offshore sweeps was pooled and ponds were sorted into groups based on grebe presence/absence in 2007. Total biomass did not differ between ponds with (range: 8.65 – 333.33, $\bar{x} \pm$ SE: 96.29 ± 24.06 mg) and without grebes (range: 16.37 – 415.47, $\bar{x} \pm$ SE: 146.40 ± 38.70 mg; independent samples *t*-test: $t_{27} = 1.16$, $p = 0.26$). There was also no difference in the total biomass of Odonata (independent samples *t*-test: $t_{14} = -0.78$, $p = 0.45$), or Coleoptera ($t_{12} = 0.60$, $p = 0.56$) between ponds with and without grebes.

Multivariate analyses of Horned Grebe habitat selection

Table 2.7 summarizes environmental variables used in the coarse environmental GLMM analyses to determine factors important in Horned Grebe pond selection. There was a large amount of support for the full model (w_i = 0.88, Table 2.8). Table 2.9 presents parameter estimates for covariates (variables that may be predictive of grebe presence/absence), odds ratios and associated confidence intervals for covariates in the best model. Both the odds ratio and lower bounds of the 95% confidence intervals for pond area (OR = 7.00, CI = 2.55, 19.18), emergent vegetation (OR = 3.47, CI = 1.48, 8.09), and riparian vegetation (OR = 2.83, CI = 1.12, 7.17) are greater than 1, indicating that these variables had a positive influence on the likelihood of grebe presence (Hosmer and Lemeshow 2000, Vittinghoff et al. 2005). There was also a significant year effect, comparing both 2007 (OR = 3.68, CI = 1.95, 6.93) and 2008 (OR = 2.35, CI = 1.27, 4.33) with 2003. As the odds ratios and upper bounds of the confidence intervals for forest within 1 km (OR = 0.04, CI = 0.01, 0.15), beaver activity (OR = 0.20, CI = 0.09, 0.45), and human disturbance (OR = 0.14, CI = 0.03, 0.64) were less than 1, these variables had a negative effect on the likelihood of grebe presence on a pond (Hosmer and Lemeshow 2000, Vittinghoff et al. 2005; Table 2.9).

I used K-S tests to examine the distribution of ponds with and without grebes across classes for a range of environmental variables in 2003, 2007 and 2008 (Figures 2.3 through 2.6, see Table 2.10 for K-S test results). In 2003 (based on the 200 pond subset) more ponds were unoccupied than in other years, and unoccupied ponds were smaller than occupied ponds (Figure 2.3). In 2003 grebes appeared to avoid heavily forested ponds, while in 2007 and 2008 grebes appeared to occur on heavily forested ponds in proportion to their availability (Figure 2.4). In 2007 and 2008 grebes were more commonly found on ponds with little forest (therefore more agriculture) surrounding them than in 2003. In 2003 grebes avoided ponds with sparse emergent vegetation (Figure 2.5a). This difference was not detected in 2007 or 2008, indicating that emergent vegetation as a significant predictor of grebe occurrence is driven primarily by vegetation measurements from 2003 (see also Table 2.7). There was no difference between occupied and unoccupied ponds in the range of riparian vegetation for any of the three years (Figure 2.6).

Values for SAV (estimating density and cover of submersed aquatic vegetation growing from the pond bottom) in 2007 and 2008 were correlated (Spearman's rho = 0.351, $p < 0.001$), ponds tended not to shift between high and low SAV values between years. Grebes were present on ponds with less SAV, both in 2007 (SAV with grebes present: $\overline{x}$ ± SE: 3.24 ± 0.08, grebes absent: 3.55 ± 0.11, Mann Whitney U: $Z = -2.11$, $p = 0.035$) and 2008 (grebes present: 3.08 ± 0.09, grebes absent: 3.39 ± 0.11, $Z = -2.39$, $p = 0.017$).

Limnology of borrow-pits

There was no inter-annual difference in TP, chlorophyll-a, and pH in ponds sampled in both 2007 and 2008 according to paired *t*-tests (presented in Table 2.11), however, TN ($t_{25} = 3.35$, $p = 0.003$) and conductivity ($t_{25} = 2.62$, $p = 0.015$) were on average higher in 2007. Ratios of TN:TP and chlorophyll-a:TP are presented in Appendix 2.3; values for both TN and TP ($r = 0.83$, $p < 0.001$) and chlorophyll-a and TP ($r = 0.61$, $p < 0.001$) are correlated (log (x+1) transformed parameters).

Environmental and limnological parameters used in the coarse + chemistry logistic regression models to predict Horned Grebe occurrence are summarized in Table 2.12. There was little support for any one model (Table 2.13); indeed the first two models can be considered equivalent. Therefore I employed model-averaging; see Table 2.14 for model-averaged parameter estimates and odds ratios. Only the odds ratio and confidence interval for beaver activity were significantly different from one, indicating that on this smaller subset of 46 ponds from which water chemistry data had been collected, Horned Grebes were more likely to be lacking when beaver activity was present (OR = 0.03, CI = 0.001, 0.76).

Beaver activity was found on 34 of 200 ponds in 2003 (17%; Horned Grebes were found on 10% of ponds with beaver activity). Beaver activity was found on 62 of 200 ponds in 2007 and 2008 (31%; Horned Grebes were found on 45% of ponds with beaver activity in 2007 and 35% in 2008). Beaver activity was associated with larger ponds (Z = -5.50, p = < 0.001) with a greater proportion of water within 1 km (Z = -5.25, p < 0.001), a greater amount of emergent vegetation (Wilcoxon signed-rank test: Z = -2.01, p = 0.04), forest (Z = -7.66, p < 0.001), riparian vegetation (Z = -3.38, p = 0.001), and higher SAV in 2007 (Z = -2.32, p = 0.20). Beaver activity was lacking from ponds with evidence of human disturbance (Z = -2.17, p = 0.03) and was not associated with distance to another water body (Z = -0.49, p = 0.63). Beaver activity was found on 16 of the 46 ponds sampled for water chemistry (34.8%; Horned Grebes were found on 62% of ponds with beaver activity in 2007 and 33% in 2008). The presence of beaver activity was positively associated with conductivity (t-test: t_{44} = -2.88, p = 0.006), but not related to TP (t_{44} = 0.56, p = 0.58), TN (t_{44} = 0.42, p = 0.68), chlorophyll-a (t_{44} = 0.33, p = 0.75), or pH (t_{44} = 0.18, p = 0.86).

Chick production on borrow-pits

Chicks were present on 76 (of 201) ponds in July and August 2007 as well as 91 ponds in June and August 2008 (Figure 2.2). Chicks were not observed in June 2007 because the survey was approximately 3 weeks earlier in 2007 than in 2008 and chicks had not yet hatched. The number of chicks produced on successful ponds ranged from 1 - 6 in 2007 ($\overline{x} \pm SE = 3.0 \pm 0.15$) and 1 - 5 in 2008 ($2.57 \pm 0.13$). One additional pond that contained one pair of adults and three chicks in June had nine grebe chicks and no adults in August 2008 (excluded from the previous summary). There were also 17 ponds that had chicks in July 2007 that were not detected in August 2007. This decline might have been due to chick mortality, but also suggests that chicks may have begun fledging by the time I surveyed ponds the first week of August 2008; ponds may have similarly been vacated by chicks by the second week of August 2007. Because of these patterns, all other analyses use the maximum number of chicks observed per pond for each year.

Chicks tended to be present on the same constructed ponds in both years (n = 201 ponds, McNemar test: $\chi^2 = 3.015$, $p = 0.082$). Chicks were present on 51/201 (25.4%) ponds in both years, present in only one year on 65/201 (32.2%) ponds and absent both years on 85/201 (42.3%). There was no difference in the number of chicks produced per pond between 2007 and 2008 (n = 116 ponds, Wilcoxon signed-ranks test: $Z = -0.241$, $p = 0.809$; Figure 2.7). Appendix 2.4 compares the number of chicks per pond in 2007 and 2008.

Of the 100 ponds where one or more adult grebes were present in May 2007, I observed one or more chicks on 63. Of the 100 ponds that lacked adult grebes in May 2007, I subsequently observed one or more chicks on 13. By June 2007, adult grebes were present on 85 ponds and chicks were eventually observed on 59 (69.4%), as well as on 17 ponds where adults were absent in June. Of the 96 ponds with adult grebes in June 2008, 75 (78.1%) eventually resulted in one or more chicks. Out of 105 ponds where no adults were recorded in June 2008, chicks were observed on 16 (15.2%) by the end of the season.

I calculated per pair brood production for Horned Grebes based on both May 2007 and June (2007 and 2008) data by counting ponds as occupied by grebes in that month if a brood was produced by the end of the season, even if adult grebes were not seen in those months. Using May 2007 data, 67% of grebe pairs present in May later produced a brood. Using June data, 74.5% of pairs produced a brood in 2007 and 81.3% in 2008.

Environmental factors – Horned Grebe chicks

Environmental variables used in coarse + chicks logistic regression analyses are summarized in Table 2.15. Because w_i for models were low (< 0.5), there was little support for one particular model either for 2007 (Table 2.16a) or 2008 (Table 2.16b). For 2007 the top two models can be considered equivalent ($\Delta i < 2$), this was true for the top five models in 2008. Model-averaged parameter estimates, odds ratios and confidence intervals are presented in Table 2.17. None of the odds ratios or confidence intervals for 2007 (Table 2.17a) were significantly different from 1, indicating that according to the variables measured, in 2007 any pond with adult grebes could potentially produce chicks. In 2008 (Table 2.17b) chicks were observed on ponds with a greater proportion of riparian vegetation (OR = 6.32, CI = 1.42, 28.05).

Agricultural versus forested ponds

There was no difference in the number of chicks produced per pond between agricultural (n = 53 ponds with chicks, $\overline{x}$ ± SE: 1.77 ± 0.23) and forested ponds (n = 23 ponds, 2.61 ± 0.46) in 2007, (Mann-Whitney U test: $Z = -1.50$, $p = 0.13$), nor was there a difference in chick production between agricultural (n = 61 ponds, 2.46 ± 0.16) and forested ponds (n = 30, 3.00 ± 0.30) in 2008 ($Z = -1.48$, $p = 0.14$).

Table 2.18 summarizes results from *t*-tests on limnological parameters, grouped into agricultural (n = 25) and forested ponds (n = 21). Both TN and TP were significantly higher in agricultural ponds than in forested ponds. Agricultural ponds were also on average 1 m deeper than forested ponds. There was a trend towards a difference in invertebrate biomass with greater biomass in forested (n = 14, 156.02 ± 35.74 mg) than agricultural (n = 15, $\overline{x}$ ± SE: 80.63 ± 21.73 mg) ponds based on Levene's test for equality of variances ($t_{21.65} = -1.80$, $p = 0.085$).

Natural wetlands

Table 2.6b summarizes Horned Grebe adult and chick occurrence on natural wetlands in 2007 and 2008. Horned Grebes occurred on two out of eight (25%) natural wetlands in 2007, and produced chicks on one. Adult grebes occurred on three out of 18 wetlands in 2008 (16.7%) and produced chicks on two. In 2007 occurrence of adult grebes on natural wetlands did not differ among survey months (n = 8, Cochran's test: $Q = 6.0$, df = 3.0, $p = 0.112$), nor did the occurrence of chicks (McNemar test: $p = 1.0$). In 2008 occurrence did not differ between June and August for adults (n = 18, $p = 0.5$) or chicks ($p = 1.00$).

Adults were absent from the same natural wetlands in both years (n=8 ponds, McNemar test: $p = 1.00$). Adults occurred on one wetland in both years, and two wetlands in only one of the two years; five natural wetlands were unoccupied in both years. In 2007 one pond supported four adult grebes, and in 2008 one pond had three grebes.

Chicks were absent from the same natural wetlands in both years (n=8 ponds, McNemar test: $p = 1.00$). There was also no difference in the number of chicks produced per natural wetland between 2007 (3 chicks) and 2008 (range: 1 - 3; n = 8, $Z = -1.00$, $p = 0.32$). In 2008 an additional 10 natural wetlands (located west of Peace River) were surveyed, however, none were occupied by Horned Grebe adults or chicks in any month. See Appendix 2.5 for a summary of environmental variables associated with all 201 constructed and 18 natural wetlands. Natural ponds in this study ranged from 0.13 to 5.31 ha (n = 18, $\bar{x}$ = 1.45, SE = 0.34). Horned Grebes were only present on wetlands ≤ 1.29 ha.

Table 2.19 summarizes limnological parameters for six natural and 46 constructed wetlands and results from independent samples *t*-tests. TN ($t_{50} = 3.53$, $p = 0.001$) and TP ($t_{50} = 4.71$, $p < 0.001$) were on average higher in natural wetlands than borrow-pits. The trophic state of natural wetlands ranged from eutrophic to hypereutrophic (ranged of TP: 49 - 471 µg/L) whereas borrow-pits ranged from mesotrophic to hypereutrophic (range of TP: 13 - 231 µg/L; Carlson 1977).

Discussion

I assessed habitat selection of Horned Grebes on borrow-pit constructed wetlands in the Peace Parkland. I determined the frequency of occurrence of Horned Grebes on constructed ponds as well as identified local pond and landscape features that were related to grebe occurrence. Chicks were produced on borrow-pits, and I investigated pond features that were related to chick production. I also directly compared chick production, limnology, and invertebrates between ponds in agricultural and forested landscapes and I investigated grebe occurrence and chick production on a small number of natural wetlands in the Peace Parkland.

Occurrence of Horned Grebes on and features of constructed ponds

I found 36% occurrence of Horned Grebes on constructed ponds in the Peace Parkland. The best models for explaining grebe presence on a pond included a variety of pond and landscape parameters that represented rapid assessments that could be easily measured during a survey. I found that Horned Grebes were present on larger ponds, with a greater amount of emergent and riparian vegetation, in primarily agricultural areas with little beaver activity or within-pond human disturbance. Ponds with grebes also had less SAV than ponds without grebes. When examining only occupied ponds, a greater amount of riparian vegetation was the only feature that explained the presence of chicks later in the summer, and only in 2008.

Table 2.20 summarizes rates of occurrence for Horned Grebes on constructed and natural wetlands throughout prairie Canada. Gingras and Beyersbergen (2003) also noted high (36%) occurrence of Horned Grebes on borrow-pits in the Peace Parkland compared to other areas. They concluded that Horned Grebes occurred on larger constructed ponds with more peripheral emergent vegetation. Gingras and Beyersbergen (2003) found that grebes may be attracted to ponds in agricultural areas as opposed to forested areas. They suggested that grebes may avoid ponds with beaver activity, as those ponds might have less emergent vegetation necessary for nesting material. Horned Grebes occupying borrow-pits in southern Saskatchewan appeared to select for the same pond types as in the Peace Parkland: larger ponds with agricultural upland and more emergent vegetation (Beyersbergen and Gingras, unpublished data).

If Horned Grebes in North America are pothole breeders, it would explain the apparent preference for wetlands that are relatively small, have distinct open water areas and are surrounded by emergent vegetation (Faaborg 1976, Sugden 1977, Ferguson and Sealy 1983). This description fits most of the borrow-pits in the Peace Parkland; however it appears that emergent vegetation was more limiting to grebes in 2003 than it was in 2007 or 2008, potentially because measurements were made in May 2003 versus August 2007, and by different observers. Riske (1976) found that potholes with breeding grebes in Alberta were semi-permanent, surrounded by more than 2/3 emergent vegetation and only partially (<1/3) surrounded by tall riparian vegetation. He also noted a preference for small potholes; 70% of the 48 potholes with grebes were smaller than 1.2 ha and the remaining 30% were between 1.2 and 2 ha. In North Dakota, Faaborg (1976) found 27 pairs of Horned Grebes on 20 natural potholes between 0.1 - 5.2 ha, although over 80% of occupied ponds were less than 2 ha. Fournier and Hines (1999) reported that 69% of Horned Grebes nesting in the NWT occurred on ponds less than 1 ha in size (but with a lower limit of 0.1 ha). Most of the borrow-pits in the NWT were within this size range, however, many of the natural wetlands surveyed were larger.

Faaborg (1976) postulated that this preference for small open sites allowed Horned Grebes to coexist in prairie areas with Eared (*Podiceps nigricollis*) and Pied-billed Grebes (*Podilymbus podiceps*). These birds breed on wetlands in the same area but have slightly different habitat preferences; Horned Grebes prefer smaller sites with more open water and less emergent vegetation than Pied-billed and Eared Grebes (Faaborg 1976, Osnas 2003). In Europe, *P. a. auritus* and the Red-necked Grebe (*Podiceps grisegena*) may be strong competitors, limiting the Horned Grebe to smaller sites (Fjeldså 1973). I did not observe any Eared Grebes on my study ponds, and only observed a Pied-billed Grebe on one occasion and a juvenile Red-necked Grebe on one other occasion. See Chapter 4 for further discussion of other species using borrow-pits.

Several measured parameters, such as distanced to road, and distance to and amount of water on the landscape, had surprisingly little power to predict Horned Grebe occurrence. I suspect these parameters were very similar for all borrow-pits as these ponds were constructed for a common purpose, located along roadsides, and thus placement was not related to hydrology of the surrounding landscape. In current pond construction practices, care is taken to avoid borrow-pit construction near (or on) ecologically sensitive areas such as wetlands (Alberta Government 1996), however regulations were not as stringent when the majority of borrow-pits in the Peace Parkland were created in the 1960s and 70s (T. McLaughlin, Alberta Transportation, personal communication).

Density of submersed macrophytes may have affected use of ponds by breeding grebes. There was significantly less SAV in ponds with grebes in both study years. Ponds with high SAV tended to be smaller than ponds with low SAV, thus use may have been ultimately related to area. Although it is possible that dense macrophytes might interfere with a grebe's diving and visibility, thus affecting foraging success, increased SAV has also been related to increased invertebrate biomass, possibly through increased amount and heterogeneity of habitat for invertebrates (Gregg and Rose 1985, Jeppesen 1998). Moreno-Ostos et al. (2008) observed an increased abundance of Little Grebes (*Tachybaptus ruficollis*) on SAV-dominated lakes in southern Spain. Borrow-pits do not display the extreme contrast of phytoplankton-dominated and SAV-dominated states reported by Bayley and Prather (2003) in their north-central Alberta study area; the mean SAV value for ponds with and without grebes were both around 3 (5-25% cover). Chlorophyll-a is also below the reported 18 µg/L cutoff for 42 of 47 (89%) ponds, indicating that most borrow-pits could be classified as "clear lakes" (whereas ponds with > 18 µg/L chlorophyll-a were classified as "turbid lakes" by Bayley et al. 2007). Of the 26 ponds sampled for chemistry in 2007 and 2008, only two ponds switched between a "clear" and "turbid" state or vice versa, while the rest remained in the clear state.

Invertebrates

I was not able to detect a difference in invertebrate biomass between ponds occupied and unoccupied by grebes. Either all ponds sampled had sufficient food supply for Horned Grebes or occupied ponds had more invertebrates initially but predation by grebes had caused a convergence in invertebrate numbers with unoccupied ponds by July. Biomass tended to be slightly higher in forested ponds than agricultural ponds, or at least more variable, which is contrary to expectations based on productivity as agricultural ponds had higher concentrations of TN and TP. If invertebrates are considered in pond selection, their influence may be masked by other factors. Fjeldså (1973) suggested that habitat selection of first year Horned Grebes in northern Europe may be based on the amount of emergent vegetation available for nest construction and anchorage, while older birds may select sites based on a variety of characteristics, including the abundance of invertebrates for food. Orians and Wittenberger (1991) suggested that yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) appear to use information on both odonate emergence and vegetation density when selecting a breeding habitat.

Limnology of constructed ponds

Limnological data for borrow-pits in the literature is rare. Borrow-pits in NWT had lower pH ($\bar{x} = 7.7$) and conductivity ($\bar{x} = 336$; Fournier and Hines 1999) than those in the Peace Parkland (pH: $\bar{x} = 7.93$, conductivity: $\bar{x} = 963.91$; Table 2.19), likely due to differences in soils and bedrock.

When I examined a smaller subset of 46 ponds in greater detail in the coarse + chemistry GLMM analyses, and compared models containing habitat parameters that had been significant in the coarse environmental GLMM with models containing limnological parameters, the top two models did not contain any limnological parameters (Table 2.13). This indicates that either water chemistry attributes are not important determinants of grebe occurrence, or that study ponds do not encompass chemistry values that exclude grebes. The only parameter from the coarse + chemistry analyses that had a significant odds ratio was beaver activity; the presence of beaver activity on a pond appears to be a deterrent to use by Horned Grebes. These results are somewhat surprising, as beavers are generally thought to be "good" for ducks (Rosell et al. 2005); increasing invertebrate biomass and abundance (McDowell and Naiman 1986), areas for roosting (Arner and Hepp 1989), and overall abundance of ducks (McKinistry et al. 2001, Nummi and Hahtola 2008). In the Peace Parkland beavers were prevalent on larger, forested ponds with more emergent vegetation, riparian vegetation and SAV. There was no evidence of beaver activity on any ponds with human activity, however, ponds with human activity were primarily in agricultural areas, and beavers may be actively removed from these ponds (Alberta Government instructions for eliminating beavers are found in Bourne (2005)). Beavers were also present on ponds with increased conductivity, potentially an outcome of beavers disturbing the sediment and introducing leaves and wood into the pond which subsequently decompose, releasing ions into the water (Rosell et al. 2005). Horned Grebes may avoid ponds with beavers as beavers are a source of disturbance. Beavers may destroy grebe nests as well, either incidentally while foraging, or deliberately, although this activity has not been described in the literature. Beaver ponds also provide habitat for muskrats (*Ondatra zibethicus*; Rosell et al. 2005), which were observed at several ponds during my surveys. Muskrats can be carnivorous (Pattie and Fisher 1999), and may represent a predator on grebe eggs.

Chick production on constructed ponds

Borrow-pits in the Peace Parkland have an average-to-high brood production per pair (percent of pairs that produced a brood; 67% of pairs present in May produced a brood), with mean brood sizes ranging from 2.6 – 3 between years. Fournier and Hines (1999) recorded an average of 60% of Horned Grebe pairs produced a brood in their NWT study area (ranging from 33 – 87% among the ten study years), with a mean brood size of 2.3. Ferguson and Sealy (1983) recorded a mean brood size at fledging of 2.75 in Manitoba Aspen Parkland. In southwest Manitoba, Osnas (2003) recorded Horned Grebe broods on 12 out of 32 (37.5%) wetlands with adult grebes, however, he did not report on mean brood size.

Osnas (2003) found that both Horned and Pied-billed Grebe brood production was positively related to wetland size, permanency, and amount of emergent vegetation. In the Peace Parkland, it appears that initial pond selection by adult grebes is important, based on a coarse subset of environmental variables. Following initial habitat selection by grebes, birds on any pond might produce chicks; ponds surrounded by a greater amount of riparian vegetation may provide more shelter to nests and growing chicks by offering protection from extreme weather events such as thunder storms. Nests of lake-nesting grebes, such as Red-necked and Western Grebes (*Aechmophorus occidentalis*) may be quite vulnerable to wind and wave action (O'Donnel and Fjeldså 1997). Riske (1976) reported that Horned Grebe nests on potholes are not as easily affected by wave action (likely due to the small size of potholes); however, Ferguson and Sealy (1983) attributed 12% egg loss from grebe nests due to waves. Riparian vegetation may also offer some shelter from egg predators; raccoon (*Procyon lotor*) was recorded as a significant grebe egg predator in Manitoba, as were American Crow (*Corvus brachyrhynchos*), American Coot (*Fulica americana*) and Black-billed Magpie (*Pica pica*), these predators destroying 38% of grebe eggs (Ferguson and Sealy 1983). The three avian predators observed by Ferguson and Sealy (1983) occur in my study area. Fournier and Hines (1999) also suspected birds to be important nest predators of Horned Grebes in the NWT, rather than mammalian predators. Other potential avian predators include Common Raven (*Corvus corax*), Red-tailed Hawk (*Buteo jamaicensis*), Great Horned Owl (*Bubo virginianus*), and various species of gulls, which are widespread in the Peace Parkland. There is evidence that corvids forage along forest edges in Alberta (Hannon and Cotterill 1998). Because borrow-pits are located along roadsides they may be considered to occur within edge habitats; predation may be higher on borrow-pits than on natural wetlands that are not associated with roads or other linear features; however, elevated nest predation was not detected for waterfowl nesting near roads in the prairie pothole region of Saskatchewan (Pasitaschniak-Arts et al. 1997), nor were consistent trends observed for artificial duck nests placed at varying distances from roads in south-central Saskatchewan (Pasitaschniak-Arts and Messier 1996).

Agricultural versus forested borrow-pits

Although limnological parameters were not significant predictors of grebe presence, agricultural borrow-pits were more enriched in nutrients, with elevated TN and TP concentrations compared to forested borrow-pits, and grebes occurred more frequently on agricultural ponds than forested ponds. Increased agricultural activities in Western Europe in the 19th century have been suggested as a reason for increased abundance of Horned Grebes in that region (O'Donnel and Fjeldså 1997). Fjeldså (1973) noted that European subspecies *P. a. auritus* is largely restricted to nesting in eutrophic waterbodies. In the Peace Parkland, brood size did not differ between agricultural and forested ponds, and higher nutrients did not translate into higher invertebrate biomass in agricultural ponds. Grebes may simply have an innate preference for ponds in more open areas (which may also be warmer), although they can breed successfully on forested ponds. Predators may be more visible in agricultural areas, and it may be easier for grebes on open ponds to take off from the water's surface without having to circle the pond to clear the trees (as observed by Dwyer (1970) on forested potholes in Manitoba).

Natural wetlands

Grebe occurrence and chick production on borrow-pits is higher than occurrence and chick production on natural wetlands located in the Peace Parkland or elsewhere in Alberta. Natural wetlands in the Buffalo Lake Moraine (BLM), Alberta, were surveyed annually from 1989 – 2003 by Alberta Fish and Wildlife (Moenting et al. 2007, Corrigan 2007). Survey data for Horned Grebes for those wetlands are summarized in Appendix 2.6 for both 1989 (a wet year) and 2003 (a dry year). The majority of Horned Grebes used ponds in the 0.1 - 2.5

ha range, well within the range of constructed ponds in my study. In 1989 the mean occupancy rate for surveyed ponds in BLM was 8.4%. This rate fell to 6.9% in the low water year of 2003. It is possible that many natural wetlands in Alberta are too large or too shallow to support Horned Grebes.

Inter-annual variability

There was some inter-annual variability unexplained by my data (Table 2.9). In particular, 2003 appeared more different from 2007 and 2008 than those years did from each other (Figs. 2.3 - 2.6). This could be due to annual fluctuations of precipitation. 2003 was a fairly dry year with total annual precipitation for Peace River of 363.5 cm, and 269.0 cm for High Level, Alberta (Environment Canada 2008). Total annual precipitation in 2007 was reported at 460.9 cm for Peace River and 428.8 cm for High Level (Environment Canada 2008). This difference in precipitation might have affected pond size in 2003 when many more of the smaller ponds remained unoccupied by grebes than in 2007 and 2008 (Fig. 2.3). Another factor that might explain the significant year effect is that it is unknown what happens to grebes that nest on borrow-pits in the Peace Parkland once they depart at the end of the season. Grebes are known to winter along coastal British Columbia and along coastal areas in the western United States (Chapter 1, Figure 1.1; Stedman 2000). To my knowledge, birds have not been individually tracked, and sources of mortality on wintering grounds and along migration routes are unknown. For conservation purposes it would be interesting to determine where birds that nest in the Peace Parkland overwinter to assess threats they might encounter the rest of the year.

Evidence for philopatry

It is unknown what proportion of birds that breed, or are born in the Peace Parkland return in following years. Evidence exists that Horned Grebes have some degree of nesting or natal site philopatry. Of 76 ponds that produced chicks in 2007, 62 were occupied by grebes in 2008, 51 of which produced chicks. Ferguson (1981) documented territorial attachment for five (of 50 banded) Horned Grebes in Minnedosa, Manitoba, recaptured on potholes where they had successfully fledged chicks the previous year. An additional two grebes were captured on wetlands near their previous breeding sites (Ferguson 1981). Grebes of both sexes returned to the breeding site, however, mate fidelity was only observed in one pair of birds. There is no survivorship data available for Horned Grebes, however, they start breeding at one year of age and lifespan has been reported as five years (Stedman 2000). Marking birds that nest on borrow-pits would allow us to determine if the same birds are using ponds year after year, or if certain ponds are used repeatedly, but by different birds.

Conclusions

Borrow-pits in the Peace Parkland provide habitat for Horned Grebes and can be considered a source of recruitment of young into the population. Grebe use and production of young is high on borrow-pits in the Peace Parkland. Horned Grebes preferentially occupy larger borrow-pits surrounded by emergent and riparian vegetation with less forest, SAV, and without the presence of beaver or human activity. Although Horned Grebes seem to nest preferentially on agricultural ponds versus forested ponds, they are equally successful on both pond types. Limnological parameters do not appear to influence habitat selection by

Horned Grebes, even though agricultural ponds are enriched in TN and TP compared to forested ponds. I was not able to detect evidence for habitat selection based on the biomass of macroinvertebrates that serve as food for grebes. If creation of habitat for Horned Grebes is a goal of conservation programs, these factors should be taken into consideration when designing wetlands for grebes, or when road construction creates new borrow-pits.

Literature Cited

Alberta Government. 1996. Conservation and reclamation information letter: environmental protection guides for pits. Report nr C&R/IL/96-5.

Arner D. H., and G. R. Hepp. 1989. Beaver pond wetland: a southern perspective. Pages 117-128 *In* Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock.

Bayley S. E., and C. M. Prather. 2003. Do wetland lakes exhibit alternative stable states? Submersed aquatic vegetation and chlorophyll in western boreal shallow lakes. Limnology and Oceanography **48**:2335-2345.

Bayley S. E., I. F. Creed, G. Z. Sass, and A. S. Wong. 2007. Frequent regime shifts in trophic states in shallow lakes on the Boreal Plain: Alternative "unstable" states? Limnology and Oceanography **52**:2002-2012.

Bethke, R. W., and T. D. Nudds. 1995. Effects of climate change and land use on duck abundance in Canadian prairie-parklands. Ecological Applications **5**:588-600.

Beyersbergen G. W., N. D. Niemuth, and M. R. Norton. 2004. Northern Prairie and Parkland Waterbird Conservation Plan. A plan associated with the waterbird conservation for the Americas initiative. Denver, Colorado: Prairie Pothole Joint Venture. 183pp.

Bourne J. 2005. Control of beaver damage. Report nr Agdex 681-1, Government of Alberta.

Burnham K. P., and D. R. Anderson. 2002. Model selection and multimodel inference. Springer-Verlag, New York.

Caldwell I. R. 2006. Use of waterfowl breeding survey data to estimate Horned Grebe populations in the Prairie Habitat Joint Venture. Canadian Wildlife Service. Unpublished report.

Carlson R. E. 1977. A trophic state index for lakes. Limnology and Oceanography **22**:361-369.

Corrigan R. 2007. Effectiveness of nest boxes in influencing population trends for Common Goldeneye (*Bucephala clangula*) and Bufflehead (*Bucephala* *albeola*) in the Buffalo Lake Moraine. M.Sc. Thesis, University of Alberta, Edmonton, Alberta, Canada.

Cramp S., and K. Simmons. 1977. Handbook of the birds of Europe the Middle East and North Africa: The birds of the western Palearctic. **1**:722.

Dwyer T. J. 1970. Waterfowl Breeding Habitat in Agricultural and Nonagricultural Land in Manitoba. The Journal of Wildlife Management **34**:130-136.

Environment Canada. 2008. National climate data and information archive. Available online: http://www.climate.weatheroffice.ec.gc.ca.

Faaborg J. 1976. Habitat selection and territorial behavior of the small grebes of North Dakota. The Wilson Bulletin **88**:390-399.

Ferguson R. S. 1981. Territorial attachment and mate fidelity by Horned Grebes. The Wilson Bulletin **93**:560-561.

Ferguson R. S., and S. G. Sealy. 1983. Breeding ecology of the Horned Grebe, *Podiceps auritus* in Southwestern Manitoba. The Canadian Field Naturalist **97**:401-408.

Fjeldså J. 1973. Feeding and habitat selection of the Horned Grebe, *Podiceps auritus* (Aves), in the breeding season. Vidensk Medd Dan Naturhist Foren **136**:57-95.

Fournier M. A., and J. E. Hines. 1999. Breeding ecology of the Horned Grebe (*Podiceps auritus*) in subarctic wetlands. Canadian Wildlife Service. Occasional paper 99.

Gingras, B. A., and G. W. Beyersbergen. 2003. Horned Grebe use of artificial ponds in forested and agricultural areas of northwestern Alberta. Poster presentation. Society of Canadian Ornithologists.

Gotelli N. J., and A. M. Ellison. 2004. A primer of ecological statistics. Sinauer Associates, Inc. Publishers, Sunderland, Massachusetts, U.S.A.

Gregg W. W., and F. Rose. 1985. Influences of aquatic macrophytes on invertebrate community structure, guild structure and microdistribution in streams. Hydrobiologia **128**:45-56.

Haig S. M., D. W. Mehlman, and L. W. Oring. 1998. Avian movements and wetland connectivity in landscape conservation. Conservation Biology **12**:749-758.

Hannon S. J., and S. E. Cotterill. 1998. Nest predation in aspen woodlots in an agricultural area in Alberta: the enemy from within. The Auk **115**:16-25.

Hoeltje S. M., and C. A. Cole. 2008. Comparison of function of created wetlands of two age classes in central Pennsylvania. Environmental Management. Available online: http://www.springerlink.com/content/5771g81311737412/. DOI: 10.1007/s00267-008-9180-9.

Hornung J. P., and A. L. Foote. 2006. Aquatic invertebrate responses to fish presence and vegetation complexity in western boreal wetlands, with implications for waterbird productivity. Wetlands **26**:1-12.

Hosmer D. W., and S. Lemeshow. 2000. Applied logistic regression. John Wiley & Sons, Inc., USA.

Jeppesen, E., M. Sondergaard, M. Sondergaard, and K. Christoffersen. 1998. The structuring role of submerged macrophytes in lakes. Springer-Verlag. New York. 423pp.

Johnson, J. B., and Omland, K. S. 2004. Model selection in ecology and evolution. Trends in Ecology and Evolution **19**: 101-108.

Keating K. A., and S. Cherry. 2004. Use and interpretation of logistic regression in habitat-selection studies. Journal of Wildlife Management **68**:774-789.

MacKenzie D. I. 2005. What are the issues with presence-absence data for wildlife managers? Journal of Wildlife Management **69**:849-860.

Maillet J. L., C. M. MacKinnon, and J. B. Pollard. 1999. Examination of the relationship between constructed impoundment age and waterbird use. Technical report series number 290, Canadian Wildlife Service.

McDowell D. M., and R. J. Naiman. 1986. Structure and function of a benthic invertebrate stream community as influenced by beaver (*Castor canadensis*). Oecologia **68**:481-489.

McKinstry M. C., P. Caffrey, and S. H. Anderson. 2001. The importance of beaver to wetland habitats and waterfowl. Journal of the American Water Resources Association **37**:1571-1577.

Mensing D. M., S. M. Galatowitsch, and J. R. Tester. 1998. Anthropogenic effects on the biodiversity of riparian wetlands of a northern temperate landscape. Journal of Environmental Management **53**:349-377.

Mitsch W. J., and J. G. Gosselink. 2000. Wetlands. John Wiley & Sons, New York.

Moenting A., L. Hamiltion, C. Paszkowski, and R. Corrigan. 2007. Species richness patterns of aquatic birds in the Buffalo Lake Moraine, Alberta, in relation to wetland size, water level, and land-use types. Alberta Conservation Association, Edmonton, Alberta, Canada. 34pp + App (83 total).

Moreno-Ostos E., M. Paracuellos, I. de Vicente, J. C. Nevado, and L. Cruz-Pizarro. 2008. Response of waterbirds to alternating clear and turbid water phases in two shallow Mediterranean lakes. Aquatic Ecology **42**:701-706.

Nummi P., and A. Hahtola. 2008. The beaver as an ecosystem engineer facilitates teal breeding. Ecography **31**:519-524.

O'Donnel C., and J. Fjeldså. 1997. Grebes - Status Survey and Conservation Action Plan. IUCN/SSC Grebe specialist group. Gland, Switzerland and Cambridge, UK. 59 pp.

Orians G. H., and J. F. Wittenberger. 1991. Spatial and temporal scales in habitat selection. The American Naturalist **137**:S29-S49.

Pasitschniak-Arts M., and F. Messier. 1996. Predation on artificial duck nests in a fragmented prairie landscape. Ecoscience **3**:436-441.

Pasitschniak-Arts M., R. G. Clark, and F. Messier. 1998. Duck nesting success in a fragmented prairie landscape: is edge effect important? Biological Conservation **85**:55-62.

Pattie, D., and C. Fisher. 1999. Mammals of Alberta. Lone Pine Publishing. Edmonton, Alberta, Canada. 240pp.

Riske M. E. 1976. Environmental and human impacts upon grebes breeding in central Alberta. Ph.D. Thesis, University of Calgary, Calgary, Alberta, Canada.

Rosell F., O. Bozser, P. Collen, and H. Parker. 2005. Ecological impact of beavers *Castor fiber* and *Castor canadensis* and their ability to modify ecosystems. Mammal Review **35**:248-276.

Saab V. 1999. Importance of spatial scale to habitat use by breeding birds in riparian forests: a hierarchical analysis. Ecological Applications **9**:135-151.

Scheffer M., S. H. Hosper, M. L. Meijer, B. Moss, and E. Jeppesen. 1993. Alternative equilibria in shallow lakes. Trends in Ecology & Evolution **8**:275-279.

Stedman, S. J. 2000. Horned Grebe (*Podiceps auritus*). The birds of North America online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the birds of North America online: http://bna.birds.cornell.edu/bna/species/505, DOI:10.2173/bna.505.

Sugden L. G. 1977. Horned Grebe breeding habitat in Saskatchwan parklands. Canadian Field Naturalist **91**:372-376.

van der Valk, A.G. 2006. The biology of freshwater wetlands. Oxford University Press, New York, USA.

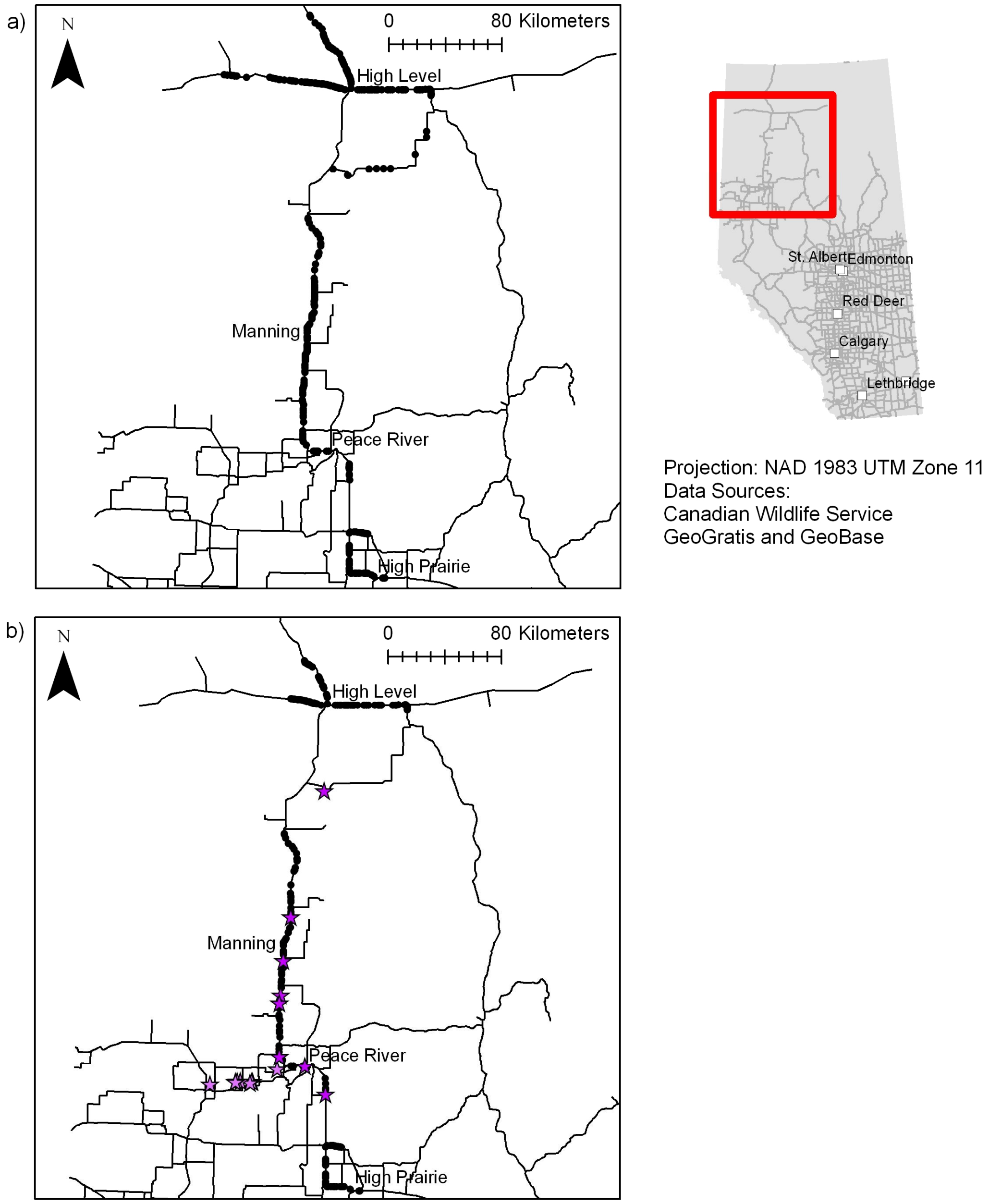
Vittinghoff E., D. V. Glidden, S. C. Shiboski, and C. E. McCulloch. 2005. Regression methods in biostatistics. Springer. New York. 344pp.

Wetzel R. G. 2001. Fundamental processes within natural and constructed wetland ecosystems: short-term versus long-term objectives. Water Science and Technology **44**:1-8.

Zampella R. A., and K. J. Laidig. 2003. Functional equivalency of natural and excavated coastal plain ponds. Wetlands **23**:860-876.

Table 2.1: Summary of dates and types of field data collected during 2003, and the 2007-2008 field seasons.

Dates	Type of data collection	Number of ponds
May 20-27 2003	-bird survey -environmental (percent emergent and riparian vegetation, beaver activity)	340 constructed
May 14-22 2007	-bird survey -environmental (area, distance to road)	330 constructed 8 natural
June 4-8 2007	-bird survey	201 constructed 7 natural
July 13-17 2007	-bird survey -environmental (SAV)	201 constructed 8 natural
July 17-21 2007	-limnological (water chemistry, depth, Secchi) -invertebrate sweeps	29 constructed
August 7-11-2007	-bird survey -environmental (percent emergent, riparian, area covered by emergent)	201 constructed 8 natural
June 23-27 2008	-bird survey -environmental (SAV)	201 constructed 18 natural
June 25-29 2008	-limnological (water chemistry)	46 constructed 6 natural
August 1-5 2008	-bird survey	201 constructed 18 natural



Projection: NAD 1983 UTM Zone 11
Data Sources:
Canadian Wildlife Service
GeoGratis and GeoBase

Figure 2.1: Map of study area and ponds surveyed in a) May 2003 and May 2007 (330 constructed), and b) June – August 2007 and June and August 2008 (201 constructed and 18 natural). Circles represent borrow-pit constructed wetlands and stars represent natural wetlands.

Table 2.2: Summary of, and abbreviations for, parameters used in models.

Parameter	**Abbreviation**
Northing (m)	utmn
Pond area (ha)	area
Distance from road to pond (m)	droad
Proportion emergent vegetation	emerg
Proportion pond area covered by emergent	areaemerg
Proportion riparian vegetation	rip
Proportion forest within 1 km	f1km
Proportion agriculture within 1 km	ag1km
Proportion water within 1km	w1km
Distance to the nearest waterbody (m)	dwater
Beaver activity (presence/absence)	beaver
Human disturbance (presence/absence)	human
Total Phosphorus (μg/L)	tp
Chlorphhyll-a (μg/L)	chl
pH	ph
Conductivity (μS)	ec

Table 2.3: Models created for coarse environmental generalized linear mixed model logistic regression analysis predicting Horned Grebe presence/absence on 200 ponds in the Peace Parkland, Alberta in 2003, 2007 and 2008. Abbreviations are defined in Table 2.2.

Theme	**Models**
Full model	utmn + area + droad + emerg + rip + f1km +w1km + dwater + beaver + human + year
Area only	area + year
All vegetation	emerg + rip + f1km + year
Local vegetation	emerg + rip + year
Landscape vegetation	f1km + year
Landscape variables	utmn + f1km + w1km + dwater + year
Local variables	area + droad +emerg + rip + beaver + human + year
Water variables	area + w1km + dwater + year
Gingras and Beyersbergen 2003 predictions	area + f1km + emerg + beaver + year
Human influence	human + droad + year

Table 2.4: Models created for coarse + chemistry generalized linear mixed model logistic regression analysis predicting Horned Grebe presence/absence on 46 ponds in the Peace Parkland, Alberta. Abbreviations are defined in Table 2.2.

Theme	**Models**
Full model	tp + chl + ph + ec + area + f1km + emerg + rip + beaver + year
Biotic influence	chl + f1km + emerg + rip + beaver + year
Abiotic influence	tp + ph + ec + area + year
Chemistry	tp + ph + ec + year
Water	tp + chl + ph + ec + year
Landscape	f1km + year
Pond morphometry	area + emerg + rip + beaver + year

Table 2.5: Models created for coarse + chicks generalized linear model logistic regression analysis predicting Horned Grebe chick presence/absence on ponds with adult Horned Grebes in 2007 (124 ponds) or 2008 (111 ponds) in the Peace Parkland, Alberta. Abbreviations are defined in Table 2.2.

Theme	**Models**
Full model	utmn + area + droad + emerg + areaemerg + rip + f1km + w1km + dwater + beaver
Area only	area
All vegetation	emerg + areaemerg + rip + f1km
Local vegetation	emerg + areaemerg + rip
Landscape vegetation	f1km
Landscape variables	utmn + f1km + w1km + dwater
Local variables	area + droad +emerg + areaemerg + rip + beaver
Water variables	area + w1km + dwater
Gingras and Beyersbergen 2003 predictions	area + emerg + f1km + beaver
Human influence	droad

Table 2.6: Summary of Horned Grebe adult and chick survey data from May 2003 to August 2008 on a) borrow-pit ponds, and b) natural wetlands in the Peace Parkland, Alberta.

a) Borrow-pit ponds

Date	Number of ponds surveyed	Number of ponds occupied by ≥ 1 adult	Proportion of ponds occupied by ≥ 1 adult	Mean number of adults/pond with ≥ 1 adult	Number of ponds with ≥ 1 chick	Proportion of ponds with ≥ 1 chick	Mean number of chicks/pond with ≥ 1 chick
May-03	330	121	0.37	1.71			
May-07	330	120	0.36	1.78			
May-03	200	83	0.42	1.71			
May-07	200	100	0.5	1.81			
Jun-07	201	85	0.42	1.34			
Jul-07	201	72	0.36	1.33	68	0.34	2.75
Aug-07	201	7	0.03	1.14	59	0.29	2.44
Jun-08	201	96	0.48	1.52	32	0.16	2.44
Aug-08	201	16	0.08	1.25	84	0.42	2.46

b) Natural wetlands

Date	Number of ponds surveyed	Number of ponds occupied by ≥ 1 adult	Proportion of ponds occupied by ≥ 1 adult	Mean number of adults/pond with ≥ 1 adult	Number of ponds with ≥ 1 chick	Proportion of ponds with ≥ 1 chick	Mean number of chicks/pond with ≥ 1 chick
May-07	8	2	0.25	2			
Jun-07	7	2	0.29	2.5			
Jul-07	8	0	0	N/A	1	0.13	3
Aug-07	8	0	0	N/A	1	0.13	1
Jun-08	18	2	0.11	2.5	1	0.06	3
Aug-08	18	0	0	N/A	1	0.06	1

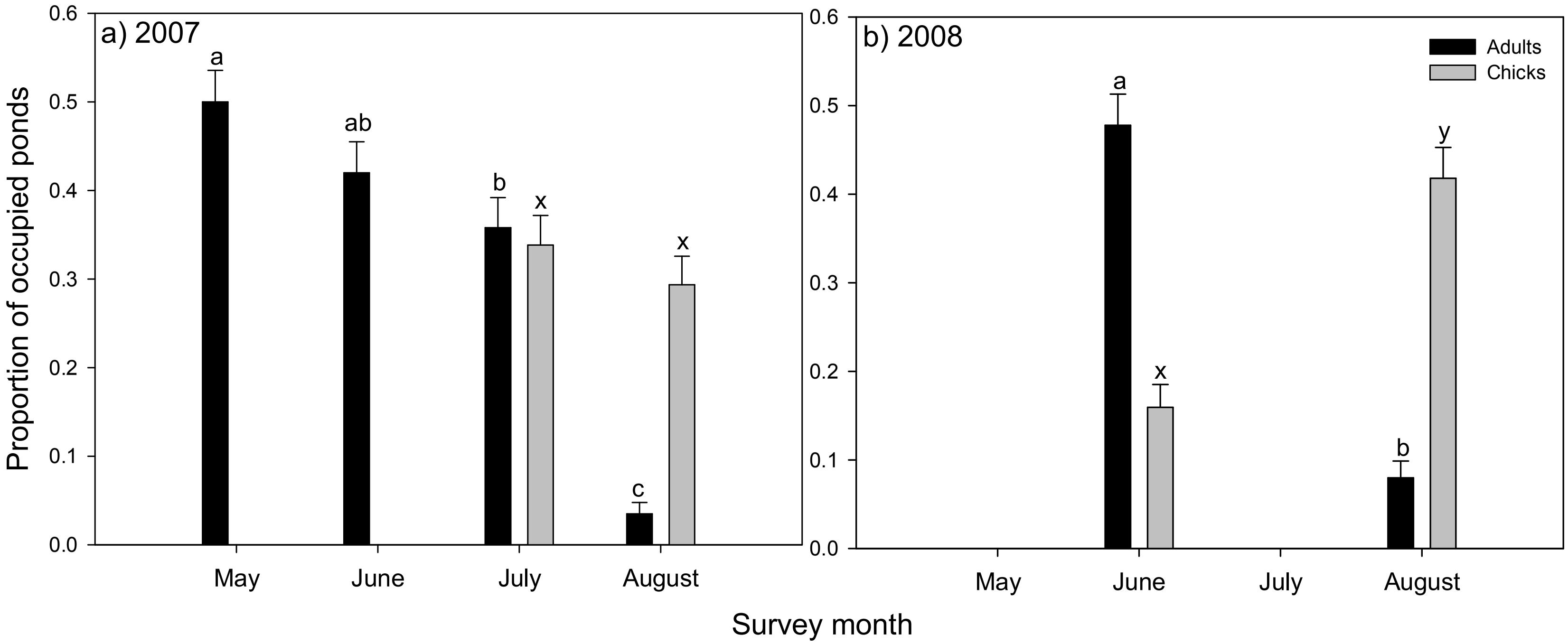


Figure 2.2: Summary of the proportion of constructed ponds occupied by Horned Grebes in the Peace Parkland, Alberta in a) May - August 2007, and b) June and August 2008. N = 200 ponds for May 2007 and 201 ponds for all other months, based on 100 ponds occupied and 100 ponds unoccupied by grebes in May 2007. See Table 1 for survey dates. Error bars indicate standard error. Letters above bars indicate results according to McNemar tests within years (a-c = adults, x, y = chicks).

Table 2.7: Summary of environmental variables recorded for 200 ponds from the Peace Parkland, Alberta. All variables but proportion of agriculture and proportion area covered by emergent were used in coarse environmental generalized linear mixed model logistic regression analyses for a) ponds with grebes and b) ponds without grebes in 2003, 2007 and 2008.

a)

	Ponds with Horned Grebes					
	2003 (n = 83)		**2007 (n = 124)**		**2008 (n = 111)**	
Parameter	**$\bar{x}$ ± SE**	**Range**	**$\bar{x}$ ± SE**	**Range**	**$\bar{x}$ ± SE**	**Range**
Northing (m)	6344704.55 ± 14495.25	6142977 - 6517349	6335208.94 ± 12052.12	6142977 - 6517349	6345660.61 ± 12828.13	6142977 - 6516385
Pond area (ha)	0.70 ± 0.05	0.11 - 1.59	0.68 ± 0.04	0.22 - 2.61	0.66 ± 0.03	0.11 - 2.34
Distance from road to pond (m)	38.11 ± 2.26	13.72 - 126.19	36.77 ± 1.79	8.23 - 126.19	38.31 ± 2.08	10.06 - 126.19
Proportion emergent vegetation	0.52 ± 0.04	0 - 1	0.72 ± 0.03	0 - 1	0.72 ± 0.03	0 - 1
Proportioin area covered by emergent	N/A	N/A	0.21 ± 0.02	0 - 0.70	0.22 ± 0.02	0 - 0.70
Proportion riparian vegetation	0.73 ± 0.03	0 - 1	0.66 ± 0.03	0 - 1	0.70 ± 0.03	0 - 1
Proportion forest within 1km	0.37 ± 0.03	0.01 - 0.95	0.38 ± 0.03	0.005 - 0.95	0.38 ± 0.03	0.005 - 0.95
Proportion agriculture within 1 km	0.55 ± 0.04	0 - 0.97	0.55 ± 0.03	0 - 0.97	0.54 ± 0.03	0 - 0.97
Proportion water within 1km	0.01 ± 0.00	0.0007 - 0.32	0.01 ± 0.00	0.001 - 0.32	0.01 ± 0.00	0.0007 - 0.19
Distance to the nearest waterbody (m)	455.81 ± 32.12	32.06 - 1738.35	476.66 ± 44.01	32.06 - 4791.98	487.19 ± 48.10	41.30 - 4791.98

b)

	Ponds without Horned Grebes					
	2003 (n = 117)		**2007 (n = 76)**		**2008 (n = 89)**	
Parameter	**$\bar{x}$ ± SE**	**Range**	**$\bar{x}$ ± SE**	**Range**	**$\bar{x}$ ± SE**	**Range**
Northing (m)	6357876.69 ± 12086.91	6144091 - 6516385	6380475.57 ± 13950.19	6146156 - 6516385	6360828.35 ± 13372.62	6146159 - 6517349
Pond area (ha)	0.59 ± 0.03	0.16 - 2.61	0.58 ± 0.03	0.11 - 1.40	0.61 ± 0.04	0.14 - 2.61
Distance from road to pond (m)	37.75 ± 1.98	8.23 - 118.87	39.74 ± 2.60	15.54 - 118.87	37.38 ± 2.12	8.23 - 109.73
Proportion emergent vegetation	0.26 ± 0.03	0 - 1	0.79 ± 0.03	0.03 - 1	0.77 ± 0.03	0 - 1
Proportion area covered by emergent	N/A	N/A	0.28 ± 0.03	0 - 1	0.26 ± 0.03	0 - 1
Proportion riparian vegetation	0.68 ± 0.03	0 - 1	0.70 ± 0.04	0 - 1	0.64 ± 0.04	0 - 1
Proportion forest within 1km	0.52 ± 0.03	0.005 - 0.96	0.58 ± 0.04	0.008 - 0.96	0.55 ± 0.04	0.008 - 0.97
Proportion agriculture within 1 km	0.40 ± 0.04	0 - 0.96	0.32 ± 0.04	0 - 0.96	0.36 ± 0.04	0 - 0.96
Proportion water within 1km	0.01 ± 0.00	0.001 - 0.11	0.01 ± 0.00	0.001 - 0.11	0.02 ± 0.00	0.001 - 0.32
Distance to the nearest waterbody (m)	531.02 ± 70.09	32.59 - 5830.66	537.57 ± 88.11	32.59 - 5830.66	515.53 ± 76.37	32.06 - 5830.66

Table 2.8: Ranking of a priori hypothesized models used in coarse environmental generalized linear mixed model logistic regression analyses to explain Horned Grebe presence/absence on 200 ponds in 2003, 2007 and 2008. See Table 2.2 for covariate abbreviations.

Models	**K**	**AICc**	Δ_i	w_i
utmn + area + droad + emerg + rip + f1km +w1km + dwater + beaver + human + year	13	686.86	0.00	0.88
area + f1km + emerg + beaver + year	7	690.78	3.93	0.12
area + droad +emerg + rip + beaver + human + year	9	705.55	18.69	7.66E-05
emerg + rip + f1km + year	6	710.34	23.48	6.99E-06
f1km + year	4	723.21	36.35	1.12E-08
utmn + f1km + w1km + dwater + year	7	728.48	41.63	8.01E-10
area + year	4	741.31	54.45	1.32E-12
emerg + rip + year	5	742.21	55.35	8.38E-13
area + w1km + dwater + year	6	743.34	56.48	4.77E-13
human + droad + year	5	743.91	57.05	3.58E-13

Table 2.9: Summary of AIC-best model from coarse environmental mixed model logistic regression predicting Horned Grebe presence/absence on 200 ponds in the Peace Parkland, Alberta. Odds ratios and confidence intervals in bold indicate odds ratios that are different from one. See Table 2.2 for covariate abbreviations.

Covariate	Coefficient	Standard Error	Odds Ratio	95% CI Odds Ratio	
intercept	-3.30	9.28			
utmn	2.39E-07	1.48E-06	1.00	1.00	1.00
area	1.95	0.51	**7.00**	**2.55**	**19.18**
droad	0.01	0.01	1.01	1.00	1.03
emerg	1.24	0.43	**3.47**	**1.48**	**8.09**
rip	1.04	0.47	**2.83**	**1.12**	**7.17**
f1km	-3.20	0.68	**0.04**	**0.01**	**0.15**
w1km	2.25	5.76	9.50	1.19E-04	7.58E+05
dwater	-1.24E-04	2.67E-04	1.00	9.99E-01	1.00
beaver (present: absent)	-1.61	0.41	**0.20**	**0.09**	**0.45**
human (present: absent)	-1.97	0.78	**0.14**	**0.03**	**0.64**
year (2007:2003)	1.30	0.32	**3.68**	**1.95**	**6.93**
year (2008:2003)	0.85	0.31	**2.35**	**1.27**	**4.33**

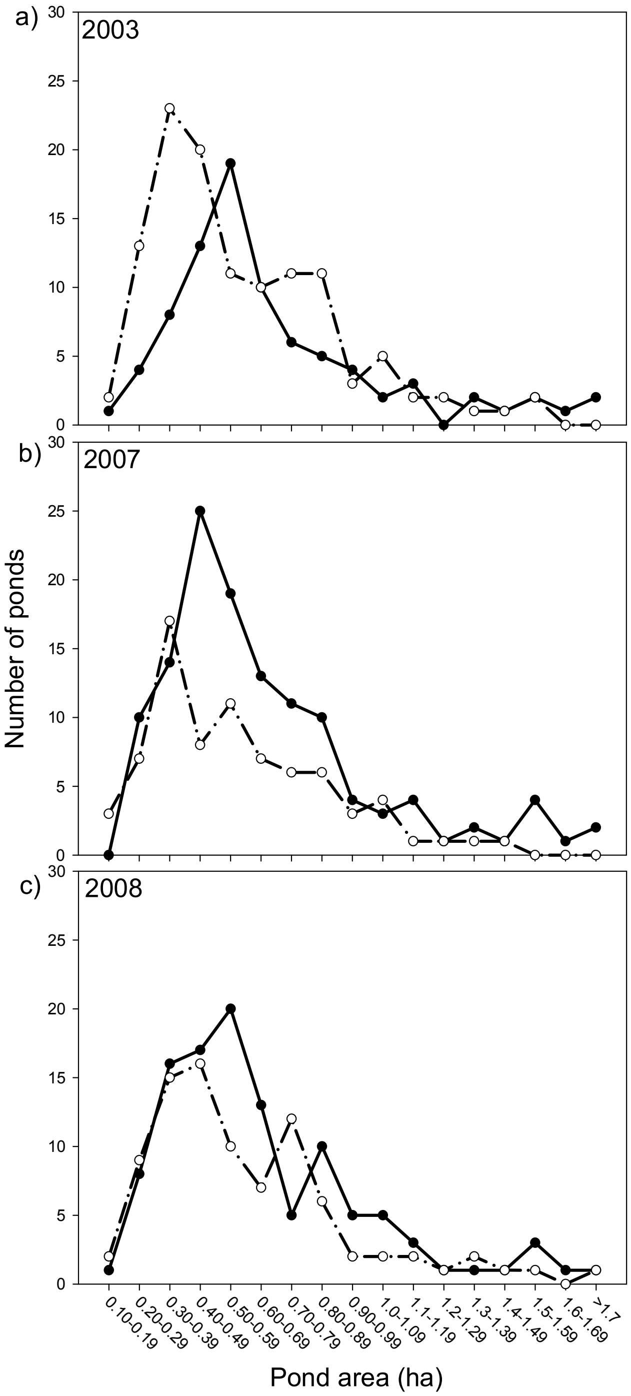


Figure 2.3: Frequency of occurrence of ponds with and without Horned Grebes across 0.10 ha size categories for 200 ponds in the Peace Parkland, Alberta in a) 2003, b) 2007, and c) 2008. Solid line = ponds with grebes, dashed line = ponds without grebes.

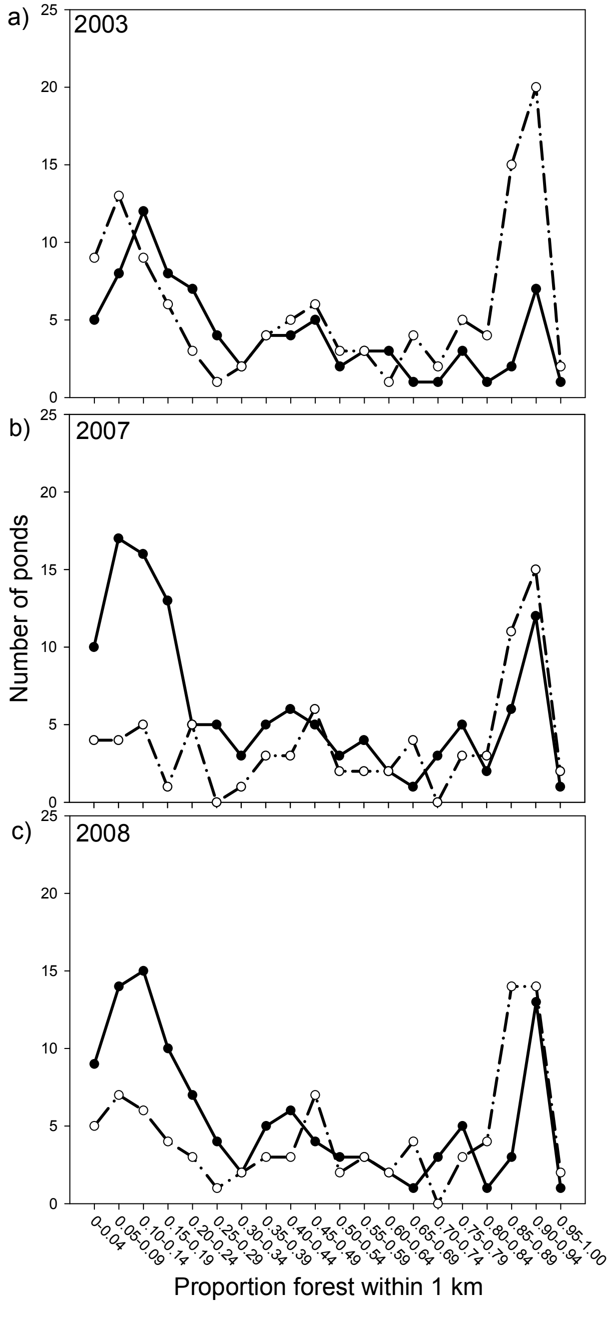


Figure 2.4: Frequency of occurrence of ponds with and without Horned Grebes across categories reflecting proportion of forest within a 1 km buffer of 200 ponds in the Peace Parkland, Alberta in a) 2003, b) 2007, and c) 2008. Solid line = ponds with grebes, dashed line = ponds without grebes.

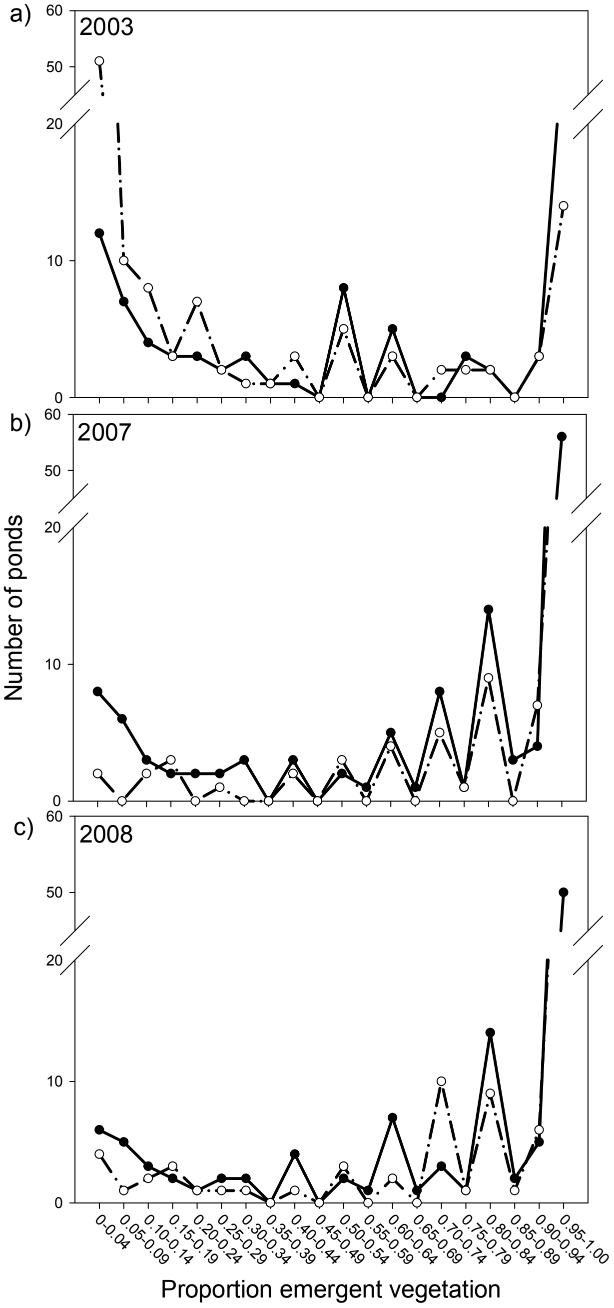


Figure 2.5: Frequency of occurrence of ponds with and without Horned Grebes across categories based on the proportion of peripheral emergent vegetation surrounding 200 ponds in the Peace Parkland, Alberta in a) 2003, b) 2007, and c) 2008. Solid line = ponds with grebes, dashed line = ponds without grebes.

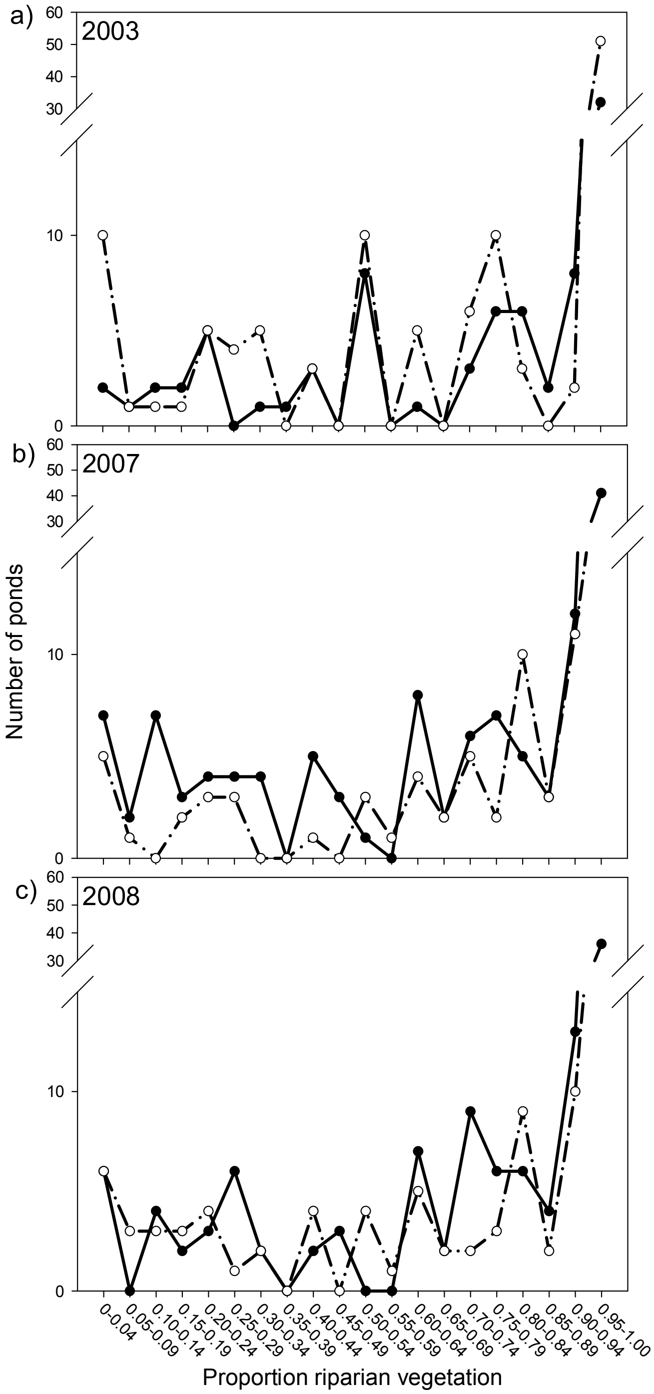


Figure 2.6: Frequency of occurrence of ponds with and without Horned Grebes across categories based on the proportion of peripheral riparian vegetation surrounding 200 ponds in the Peace Parkland, Alberta in a) 2003, b) 2007, and c) 2008. Solid line = ponds with grebes, dashed line = ponds without grebes.

Table 2.10: Summary of Kolmogorov-Smirnov test results comparing the frequency of occurrence of ponds with and without Horned Grebes across size, land-cover and emergent and riparian vegetative cover categories in 2003, 2007 and 2008 for 200 ponds in the Peace Parkland, Alberta (see Figures 2.3 – 2.6). *P* values in bold indicate statistical significance.

	Year	*Z*	*p*
Pond area	2003	1.39	**0.041**
	2007	1.2	0.112
	2008	0.96	0.317
Forest within 1 km of pond	2003	1.75	**0.004**
	2007	2.16	**<0.001**
	2008	1.94	**0.001**
Emergent Vegetation	2003	2.27	**<0.001**
	2007	0.72	0.683
	2008	0.78	0.579
Riparian Vegetation	2003	0.7	0.72
	2007	0.8	0.537
	2008	0.68	0.752

Table 2.11: Paired *t*-test results comparing limnological parameters measured between 2007 and 2008 on 26 ponds in the Peace Parkland, Alberta.

	2007		**2008**				
Parameter	**$\bar{x}$ ± SE**	**Range**	**$\bar{x}$ ± SE**	**Range**	***t***	***df***	***p***
Total phosphorus (µg/L)	42.54 ± 5.29	17 - 118	42.69 ± 6.10	16 - 151	-0.04	25	0.97
Total nitrogen (µg/L)	1166.62 ± 72.04	685 - 2170	882.96 ± 67.16	495 - 2120	3.35	25	**0.003**
Chlorophyll-a (µg/L)	5.24 ± 1.23	0.14 - 26.23	6.07 ± 2.50	0.43 - 59.68	-0.24	25	0.81
pH	7.92	7.2 - 10.40	7.94	7.35 - 9.25	0.94	25	0.36
Conductivity (µS)	1083.08 ± 97.51	270 - 1980	1029.04 ± 92.28	195 - 1925	2.62	25	**0.015**

Table 2.12: Summary of limnological and environmental variables for 46 ponds from the Peace Parkland, Alberta. All variables but total nitrogen were used in the coarse + chemistry generalized linear mixed model logistic regression analyses predicting Horned Grebe presence/absence in 2007 – 2008.

	Ponds with Horned Grebes				**Ponds without Horned Grebes**			
	2007 (n = 33)		**2008 (n = 27)**		**2007 (n = 13)**		**2008 (n = 19)**	
Parameter	**$\bar{x}$ ± SE**	**Range**	**$\bar{x}$ ± SE**	**Range**	**$\bar{x}$ ± SE**	**Range**	**$\bar{x}$ ± SE**	**Range**
Total nitrogen (µg/L)	1020.15 ± 63.83	449 - 2470	990.33 ± 75.35	449 - 2470	961.15 ± 128.18	495 - 2120	1022.16 ± 92.09	495 - 2120
Total phosphorus (µg/L)	51.61 ± 6.97	13 - 231	49.19 ± 7.75	13 - 231	53.77 ± 13.08	16 - 151	56.53 ± 10.16	16 - 151
Chlorphhyll-a (µg/L)	8.97 ± 3.60	0 - 116.84	9.56 ± 4.41	0 - 116.84	7.05 ± 4.44	0 - 59.68	6.81 ± 3.01	0.38 - 59.68
pH	7.97	7.4 - 9.25	8.00	7.4 - 9.25	7.85	7.35 - 8.70	7.84	7.35 - 8.7
Conductivity (µS)	906.36 ± 81.53	190 - 1925	899.26 ± 90.50	190 - 1925	1110.00 ± 155.04	195 - 1990	1055.79 ± 122.51	195 - 1990
Area (ha)	0.62 ± 0.04	0.30 - 1.16	0.61 ± 0.04	0.301 - 1.16	0.56 ± 0.06	0.14 - 0.84	0.59 ± 0.05	0.14 - 0.89
Proportion forest within 1km	0.44 ± 0.06	0.01 - 0.93	0.38 ± 0.07	0.01 - 0.93	0.55 ± 0.09	0.008 - 0.91	0.59 ± 0.07	0.008 - 0.91
Proportion emergent	0.73 ± 0.06	0 - 1	0.71 ± 0.07	0 - 1	0.75 ± 0.09	0.15 - 1	0.77 ± 0.07	0 - 1
Proportion riparian	0.72 ± 0.05	0 - 1	0.68 ± 0.06	0 - 1	0.79 ± 0.07	0.05 - 1	0.83 ± 0.05	0.05 - 1

Table 2.13: Ranking of a priori hypothesized models used in coarse + chemistry generalized linear model logistic regression analyses to predict Horned Grebe presence/absence on 46 constructed ponds sampled for water chemistry in the Peace Parkland, Alberta. See Table 2.2 for covariate abbreviations.

Models	**K**	**AICc**	Δ_i	w_i
area + emerg + rip + beaver + year	7	107.75	0.00	0.48
f1km + year	4	108.18	0.43	0.39
tp + ph + ec + year	6	111.75	4.01	6.45E-02
chl + f1km + emerg + rip + beaver + year	8	113.09	5.34	3.30E-02
tp + ph + ec + area + year	7	113.95	6.20	2.15E-02
tp + chl + ph + ec + year	7	114.55	6.80	1.60E-02
tp + chl + ph + ec + area + f1km + emerg + rip + beaver + year	12	119.75	12.01	1.18E-03

Table 2.14: Summary of model-averaged parameter estimates, unconditional standard error and odds ratios from the coarse + chemistry generalized linear mixed model logistic regression analysis predicting Horned Grebe presence/absence on 46 ponds in the Peace Parkland, Alberta. Odds ratios and confidence intervals in bold indicate odds ratios are different from one. See Table 2.2 for covariate abbreviations.

Covariate	Model-averaged parameter estimate	Unconditional SE	Odds Ratio	95% CI Odds Ratio	
intercept	-6.15	13.52	2.12E-03	6.61E-15	6.81E+08
tp	0.00	0.02	9.98E-01	0.97	1.03
chl	0.01	0.04	1.01	0.93	1.10
ph	2.69	1.86	14.79	0.38	567.98
ec	0.00	0.00	9.98E-01	9.95E-01	1.00
area	5.25	3.58	190.38	0.17	2.11E+05
f1km	-3.14	2.2	0.04	5.79E-04	3.21
emerg	-0.13	1.90	0.88	0.02	36.16
rip	-3.30	2.46	0.04	2.99E-04	4.58
beaver (present: absent)	-3.54	1.67	**0.03**	**0.00**	**0.76**
year (2008:2007)	-1.39	0.79	0.25	0.05	1.17

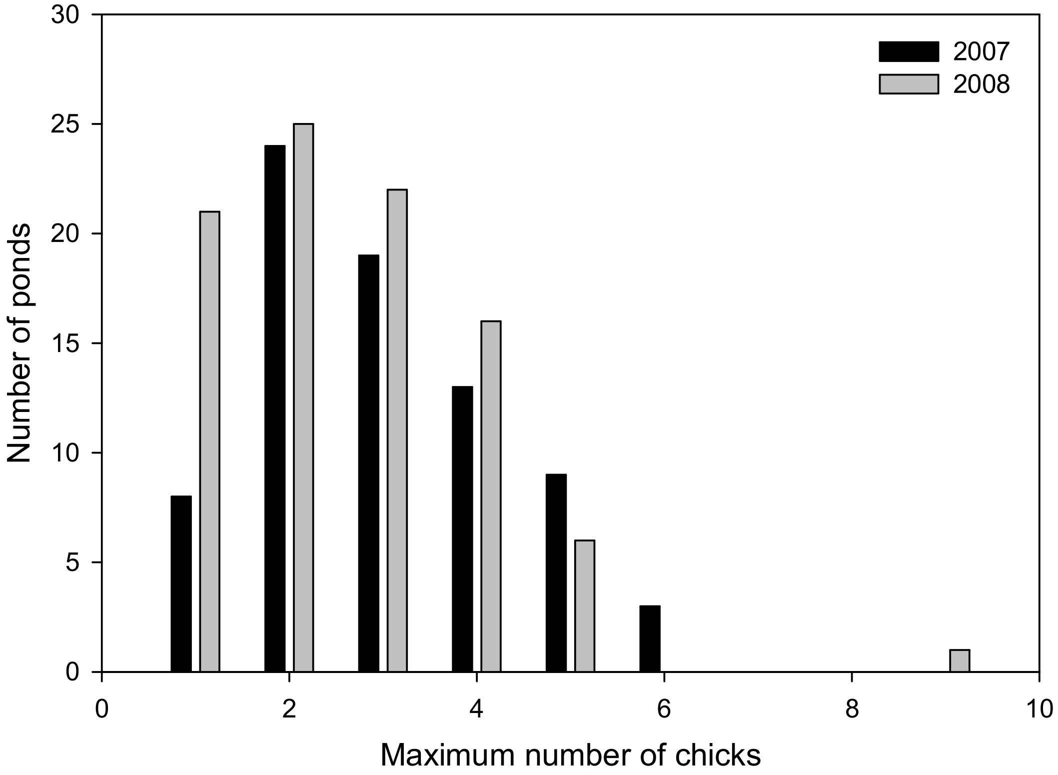


Figure 2.7: Frequency of occurrence of differing numbers of Horned Grebe chicks on ponds in the Peace Parkland, Alberta in 2007 (76 ponds) and 2008 (91 ponds). Data based on surveys in July and August 2007 and June and August 2008.

Table 2.15: Summary of environmental variables for 124 ponds in 2007 and 111 ponds in 2008 from the Peace Parkland, Alberta. All variables but proportion agriculture were used in coarse + chicks generalized linear model logistic regression analyses for predicting Horned Grebe chick presence/absence on ponds occupied by adult grebes.

	Ponds with chicks				Ponds without chicks			
	2007 (n = 76)		2008 (n = 90)		2007 (n = 48)		2008 (n = 21)	
Variable	$\bar{x}$ ± SE	Range	$\bar{x}$ ± SE	Range	$\bar{x}$ ± SE	Range	$\bar{x}$ ± SE	Range
Northing (m)	6338920.42 ± 15589.14	6142983 - 6517349	6342679.46 ± 13764.05	6142983 - 6515865	6329332.42 ± 19151.83	6142977 - 6513150	6358437 ± 34071.80	6142977 - 6516385
Pond area (ha)	0.63 ± 0.04	0.22 - 2.61	0.67 ± 0.04	0.11 -2.34	0.75 ± 0.06	0.22 – 2.34	0.58 ± 0.04	0.30 - 1.07
Distance from road to pond (m)	36.95 ± 2.61	8.23 - 126.19	37.36 ± 2.21	10.06 - 126.19	36.48 ± 2.11	10.06 - 85.04	42.41 ± 5.61	15.54 - 118.87
Proportion emergent vegetation	0.71 ± 0.04	0 - 1	0.74 ± 0.03	0 - 1	0.72 ± 0.05	0 - 1	0.65 ± 0.09	0 - 1
Proportion pond area covered by emergent	0.22 ± 0.02	0 - 0.70	0.22 ± 0.02	0.00 - 0.70	0.19 ± 0.02	0 - 0.70	0.21 ± 0.04	0.00 - 0.60
Proportion riparian vegetation	0.68 ± 0.04	0 - 1	0.73 ± 0.03	0 - 1	0.61 ± 0.05	0 - 1	0.55 ± 0.09	0 - 1
Proportion agriculture within 1 km	0.55 ± 0.04	0 - 0.96	0.54 ± 0.04	0 - 0.97	0.54 ± 0.05	0 - 0.97	0.55 ± 0.07	0 - 0.96
Proportion forest within 1 km	0.38 ± 0.04	0.005 - 0.95	0.38 ± 0.03	0.01 - 0.95	0.37 ± 0.05	0.01 - 0.91	0.39 ± 0.07	0.01 - 0.93
Proportion water within 1 km	0.01 ± 0.00	0.00 - 0.19	0.01 ± 0.00	0.00 - 0.19	0.02 ± 0.01	0.00 - 0.32	0.01 ± 0.00	0.00 - 0.04
Distance to the nearest waterbody (m)	534.30 ± 67.31	32.06 - 4791.98	509.72 ± 57.75	41.30 - 4791.98	385.38 ± 36.86	49.45 - 941.95	390.67 ± 55.52	89.96 - 857.43

Table 2.16: Ranking of a priori hypothesized models used in coarse + chicks generalized linear model logistic regression analyses to predict Horned Grebe chick presence/absence on a) 124 ponds in 2007, and b) 111 ponds in 2008 with adult grebes in the Peace Parkland, Alberta. See Table 2.2 for covariate abbreviations.

a) 2007

Models	**K**	**AICc**	Δ_i	$\mathbf{w}_i$
area + w1km + dwater	5	166.188	0.00	0.433
area	3	167.07	0.88	0.279
f1km	3	169.71	3.52	0.074
droad	3	169.71	3.52	0.074
utmn + f1km + w1km + dwater	6	169.848	3.66	0.070
emerg + rip + areaemerg	5	171.048	4.86	0.038
area + f1km + emerg + beaver	6	173.048	6.86	0.014
emerg + rip + f1km + areaemerg	6	173.218	7.03	0.013
area + droad +emerg + rip + beaver + areaemerg	8	175.632	9.44	0.004
utmn + area + droad + dwater + w1km + f1km + emerg + rip + areaemerg + beaver	12	179.241	13.05	0.001

b) 2008

Models	**K**	**AICc**	Δ_i	$\mathbf{w}_i$
emerg + rip + areaemerg	5	109.14	0.00	0.36
area	3	110.66	1.52	0.17
emerg + rip + f1km + areaemerg	6	110.68	1.54	0.17
droad	3	111.05	1.91	0.14
f1km	3	111.89	2.75	0.09
area + w1km + dwater	5	113.88	4.74	0.03
area + droad +emerg + rip + beaver + areaemerg	8	114.05	4.91	0.03
area + f1km + emerg + beaver	6	116.23	7.09	0.01
utmn + f1km + w1km + dwater	6	116.66	7.52	0.01
utmn + area + droad + dwater + w1km + f1km + emerg + rip + areaemerg + beaver	12	121.32	12.18	0.00

Table 2.17: Summary of model-averaged parameter estimates and odds ratios for coarse + chicks logistic regression analyses predicting Horned Grebe chick presence/absence on a) 124 ponds in 2007 and b) 111 ponds in 2008 with adult grebes in the Peace Parkland, Alberta. Odds ratios and 95% confidence intervals in bold indicate significant effects of that covariate. See Table 2.2 for covariate abbreviations.

a) 2007

Covariate	**Model-averaged parameter estimate**	**Unconditional SE**	**Odds Ratio**	**95% CI Odds Ratio**	
intercept	-0.15	1.85			
utmn	0.00	1.65E-06	1.00	1.00	1.00
area	-0.78	0.50	0.46	0.17	1.22
droad	0.00	0.01	1.00	0.98	1.02
emerg	-0.62	0.78	0.54	0.12	2.52
areaemerg	2.00	1.54	7.40	0.36	151.90
riparian	0.48	0.55	1.62	0.55	4.77
f1km	0.01	0.67	1.01	0.27	3.79
w1km	-4.90	6.17	0.01	4.18E-08	1.32E+03
dwater	0.00	7.22E-04	1.00	1.00	1.00
beaver (present: absent)	-0.16	0.52	0.85	0.31	2.34

b) 2008

Covariate	**Model-averaged parameter estimate**	**Unconditional SE**	**Odds Ratio**	**95% CI Odds Ratio**	
intercept	0.38	1.23			
utmn	-7.54E-07	2.14E-06	1.00	1.00	1.00
area	0.80	0.82	2.23	0.45	11.22
droad	-0.01	0.01	0.99	0.97	1.01
emerg	1.47	1.06	4.37	0.55	34.82
areaemerg	-1.22	1.98	0.29	0.01	14.41
riparian	1.84	0.76	**6.32**	**1.42**	**28.05**
f1km	-0.49	0.90	0.61	0.10	3.59
w1km	3.31	15.55	27.52	1.60E-12	4.74E+14
dwater	8.53E-04	9.35E-04	1.00	0.99	1.00
beaver (present: absent)	-0.15	0.71	0.86	0.21	3.50

Table 2.18: Summary of limnological parameters collected in 2008 from 46 ponds in the Peace Parkland, Alberta. Data are grouped by agricultural (> 49.9% forest within 1 km of pond) and forested (≥ 50% forest) ponds, and present results from independent samples *t*-test. P-values in bold indicate statistical significance.

	Agricultural (n = 25)		**Forested (n = 21)**				
Parameter	**$\bar{x}$ ± SE**	**Range**	**$\bar{x}$ ± SE**	**Range**	***t***	**df**	***p***
Total phosphorus (µg/L)	62.04 ± 8.65	21 - 231	40.52 ± 8.15	13 - 151	2.91	44	**0.01**
Total nitrogen (µg/L)	1133.44 ± 83.74	626 - 2470	848.76 ± 64.83	449 - 1400	2.95	44	**0.01**
Chlorophyll-a (µg/L)	11.58 ± 5.07	0 - 116.84	4.67 ± 1.44	0 - 29.88	1.12	44	0.27
pH	8.02	7.50 - 9.25	7.85	7.35 - 9.00	1.53	44	0.13
Conductivity (µS)	897.00 ± 98.51	190 - 1990	1043.57 ± 110.07	195 -1925	-0.75	44	0.46
Depth (m) *	3.27 ± 0.31	0.75 - 5.50	2.20 ± 0.26	0.90 - 3.80	2.62	27	**0.01**
Secchi depth (m) *	1.61 ± 0.25	0.73 - 3.25	1.39 ± 0.24	0.58 - 2.55	0.62	18	0.54

* Depth and Secchi based on 29 ponds sampled in 2007 (15 agricultural 14 forested), Secchi data based only on 20/29 ponds not visible to bottom.

Table 2.19: Summary of limnological parameters collected in 2008 and results of independent samples *t*-tests comparing six natural and 46 constructed ponds in the Peace Parkland, Alberta.

	Natural (n = 6)		**Constructed (n = 46)**				
Parameter	**$\bar{x}$ ± SE**	**Range**	**$\bar{x}$ ± SE**	**Range**	***t***	***df***	***p***
Total phosphorus (µg/L)	193.50 ± 59.55	49 - 471	52.22 ± 6.14	13 - 231	4.71	50	**<0.001**
Total nitrogen (µg/L)	1843.33 ± 369.05	1010 - 2970	1003.48 ± 57.72	449 - 2470	3.53	50	**0.001**
Chlorophyll-a (µg/L)	3.73 ± 1.44	0.27 - 8.29	9.01 ± 3.03	0.36 -	-0.93	50	0.356
pH	7.54	7.25 - 9.25	7.93	7.35 - 9.25	-1.01	50	0.317
Conductivity (µS)	815.00 ± 243.63	395 - 1990	963.91 ± 73.41	190 - 1990	-0.67	50	0.503
Depth (m) *			2.75 ± 0.22	0.75 - 5.50			
Secchi depth (m) *			1.51 ± 0.17	0.58 - 3.25			

* Depth and Secchi based on 29 ponds sampled in 2007, Secchi data based only on 20/29 ponds not visible to bottom

Table 2.20: Summary of frequencies of occurrence of breeding Horned Grebes in surveys conducted throughout Canada.

Location	Month of survey	# ponds occupied/ # ponds surveyed	% Occupancy	Constructed or natural ponds	Citation
Northwestern Alberta (Peace Parkland)	Mid - late May	123/340	36.20%	constructed	Gingras and Beyersbergen 2003
North-central Alberta (Grande Prairie to Peace River)	Mid - late May	21/216	9.70%	constructed	Environment Canada, unpublished data (WBGS survey)
Southern Saskatchewan (around Regina and Saskatoon)	Mid - May to early June	72/254	28.30%	constructed	Beyersbergen and Gingras, unpublished data
Northwest Territories (west of Yellowknife)	May	87.5/575	15.2%*	pooled natural and constructed	Fournier and Hines 1999
Southeast Saskatchewan (east of Saskatoon)	Mid-late May	64/455	14.1%**	natural	Sugden 1977
Southwestern Manitoba	Determined over season	32/180	17.70%	natural	Osnas 2003
Central Alberta (Buffalo Lake Moraine)	Early - mid May	51/736	6.90%	natural	Moenting et al. 2007, Corrigan 2007

*averaged over 11 survey years

**averaged over 2 survey years

Chapter 3

An investigation of habitat selection by the Horned Grebe (*Podiceps auritus*) using stable isotope analysis

Introduction

For an individual animal, the choice of where to breed is arguably one of the most important decisions it will make. This is particularly true for animals that travel long distances to breed, such as migratory birds, and it is important to gain an understanding of the cues that species might use in selecting a breeding habitat, in order to conserve and manage appropriate habitat (Cody 1981).

The Horned Grebe (*Podiceps auritus*) is a migratory diving bird that breeds in northwestern Canada and the United States on small freshwater wetlands (Stedman 2000). Like other species of grebes, the Horned Grebe is largely restricted to breeding ponds once pairs arrive in the spring and egg laying commences (Stedman 2000); pairs likely rely exclusively on food resources within the pond for nourishment of themselves and their young. Thus, pond selection is crucial for breeding success. During the breeding season, Horned Grebes feed primarily on aquatic macroinvertebrates (Stedman 2000) and have been described as opportunistic feeders, exploiting locally available prey (Fjeldså 1973a).

Breeding bird survey (BBS) data for the Horned Grebe indicate a Canada-wide mean annual decline of 2.7%/year from 1968-2007, and in Alberta alone, at the heart of the Horned Grebe breeding area, a mean annual decline of 7.3%/year from 1968-2007 (Downes and Collins 2008). Worldwide waterbird population declines are primarily attributed to the destruction and degradation of natural wetland habitat through conversion to urban, industrial, and agricultural uses (Bethke and Nudds 1995). In North America, agricultural conversion is the main factor contributing to wetland loss (Mitsch and Gosselink 2000), while climate change threatens small prairie wetlands that remain (Bethke and Nudds 1995). Up to 50% of wetlands have been destroyed in the Northern Prairie and Parkland region of Canada and the United States, an area containing the most important waterfowl breeding habitat in North America, as well as much of the Horned Grebe's breeding range (Beyersbergen et al. 2004).

Despite the decline in natural wetland habitat, Horned Grebes have been observed nesting on borrow-pit wetlands, small rectangular roadside ponds created during road construction, in the Peace Parkland of northwest Alberta (Gingras and Beyersbergen 2003) and the Northwest Territories (Fournier and Hines 1999). I conducted a survey of 330 borrow-pit wetlands throughout the Peace Parkland in May 2007 and documented 36% occurrence of Horned Grebes (Chapter 2), a high level of occupancy of available wetlands compared to other areas of the prairies (Environment Canada, unpublished data, Beyersbergen and Gingras, unpublished report). My survey suggests that constructed wetlands may be important habitat for grebes in Alberta. I also have evidence that many of the same ponds are occupied year after year by breeding grebes (Chapter 2), indicating that patterns of habitat selection may be consistent over longer time periods.

To investigate what factors influence the selection of breeding ponds by Horned Grebes, I used stable isotope analysis (SIA) to compare food-webs of borrow-pit ponds with breeding Horned Grebes with those of ponds where grebes were absent. I examined whether differences in food-web structure and the nature of potential food resources could help explain why certain ponds are selected for breeding and others are not. Food-web analysis may also reveal the effects of Horned Grebes as top predator on these wetland systems, as top predators can induce trophic cascades that are reflected in food-web structure (Pace et al. 1999).

Stable isotope analysis can be an effective tool for studying food-webs in lake ecosystems (see Peterson and Fry 1987 and Kelly 2000 for reviews). Less invasive and more integrative than stomach contents analysis (Vander Zanden et al. 1997), and more informative than foraging observations, SIA, particularly in studies of wild birds, can provide information regarding diet and the source of nutrients, e.g. aquatic versus terrestrial, or marine versus freshwater (Peterson and Fry 1987).

The isotopes ^{13}C and ^{15}N are found naturally in the environment, but in much lower abundance than ^{12}C and ^{14}N (Peterson and Fry 1987). Due to fractionation events, the ^{15}N isotope is enriched by 3 – 4‰ relative to prey items (3.4‰ on average), which allows for the determination of trophic structure of an ecosystem (DeNiro and Epstein 1981, Vander Zanden and Rasmussen 1999) and the trophic position of species of interest (Vander Zanden et al. 1997). The ratio of ^{13}C to ^{12}C, on the other hand, remains relatively constant along a food chain and is enriched little by the diet (1‰ on average), which allows for the determination of sources of primary production (DeNiro and Epstein 1978, Vander Zanden and Rasmussen 1999).

I analyzed stable isotope ratios of albumen from eggs as a representative tissue for Horned Grebes; eggs are formed from nutrients aquired by the adult female (Hobson 1995). In a study of Mallard (*Anas platyrhynchos*), falcons (*Falco* sp.) and Japanese Quail (*Coturnix japonica*), egg albmen was enriched in ^{15}N on average by 3.4‰ over females' dietary items (Hobson 1995). Delta ^{15}N and $\delta^{13}C$ values for egg albumen can also help determine whether nutrients invested in eggs by female birds are imported from the wintering grounds or originate at the breeding site (Hobson et al. 2000). For Horned Grebes, isotope signatures of egg albumen could indicate whether nutrients were of marine (wintering) or freshwater (breeding) origin, as marine derived tissues are enriched in ^{13}C and ^{15}N (Hobson et al. 1997) and thus have higher $\delta^{13}C$ and $\delta^{15}N$.

In this study I complemented SIA of food-webs with sampling of pond invertebrates to determine if the biomass of prey organisms of grebes differed among ponds. I predicted that food-webs would differ between ponds occupied and unoccupied by Horned Grebes, as reflected by the trophic position of key taxa. I also expected higher invertebrate biomass in ponds with grebes than ponds without grebes. I predicted that Horned Grebes would occupy the highest trophic position in ponds, and that they use nutrients derived from the breeding pond in egg formation, as demonstrated for Red-necked Grebes in Alberta (Paszkowski et al. 2004).

Methods

Study sites

Study ponds were located between High Prairie and Manning, in northwest Alberta (55.46164 N, -117.01140 W to 56.64793 N, -117.65500 W) at the southern end of the Peace Parkland, a heterogeneous mix of boreal mixed wood and grasslands that has largely been converted to agriculture (Figure 3.1). Thirteen of 14 ponds that I sampled were greater than 1 km apart, two ponds were separated by 75 m (ponds 341 and 55).

In July 2007 and June 2008 I sampled the chemistry of study ponds, including pH, conductivity (with handheld meters), TN, TP and chlorophyll-a. I also measured pond area (with a digital rangefinder), maximum depth, and Secchi depth. As described in Chapter 2, dominant land-cover was characterized for each pond using a 500 m buffer in ArcGIS Version 9.2 (ESRI 2007). A pond was classified as agricultural or forested based on dominant land cover (present in ≥ 50%) within the buffer. Table 3.1 summarizes physical and chemical characteristics of study ponds. Ponds sampled in this study were small ($\bar{x} \pm$ SE: 0.51 ± 0.06 ha) and productive (TP = 54.69 ± 8.77 µg/L), ranging from mesotrophic to hypereutrophic (trophic state based on TP; Carlson 1977).

Field collection of material for SIA

In June 2007 I collected invertebrates, amphibian larvae, fish and grebe eggs for SIA from study ponds. Seven ponds had a breeding pair of Horned

Grebes and seven were unoccupied by grebes. Horned Grebe nests are fairly conspicuous, and were located by navigating the perimeter of the pond on foot or with a small kayak, while observing grebes for defensive or aggressive behaviour. One egg was taken under permit (permit number CWS07-A005) from each of the seven ponds where a breeding pair was present. The cleanest, youngest egg (Horned Grebes quickly stain eggs by covering them with muddy vegetation; Stedman 2000) was taken from nests on six ponds. On one pond (pond 15) only one drowned egg, located next to a wet sunken nest, was found and salvaged. All eggs were frozen to halt development for later processing. Removal of one egg from each Horned Grebe nest in this study should have had no negative effect on brood size. Grebes lay more eggs than hatch (Stedman 2000) and egg removal studies conducted in Manitoba by Arnold (1990) documented replacement of removed eggs by female Horned Grebes.

All ponds were checked for the presence of fish by setting four Gee minnow traps overnight. Four ponds contained fish in June 2007. Of these, three contained brook stickleback (*Culaea inconstans*); ponds 15 (occupied by grebes) and 50 (unoccupied) only contained stickleback, pond 94 (unoccupied) contained brook stickleback as well as northern redbelly dace (*Phoxinus eos*). Pond 36 (occupied) was stocked with rainbow trout (*Oncorhynchus mykiss*) and also contained pearl dace (*Margariscus margarita*). However I was unsuccessful in trapping northern redbelly dace or rainbow trout when collecting additional samples in July 2007. Wood frog (*Lithobates sylvaticus*) tadpoles were found at five ponds. Invertebrates were sampled at all 14 ponds by sweeping along the shoreline with a standard D-frame invertebrate dip net; some larger nektonic taxa were also caught in minnow traps. Snails were collected at each pond, and served as long-lived primary consumers for the establishment of baseline values to standardize variable $\delta^{15}N$ signatures among ponds (Cabana and Rasmussen 1996). All invertebrates, tadpoles, and fish were held alive overnight to allow them to void their guts, then euthanized, packaged in aluminum foil and frozen for later processing. A range of invertebrates common within and between ponds were collected in order to sample potential prey of grebes as well as encompass a range of trophic positions. Invertebrates were generally identified to Order or Suborder unless sufficient quantities of organisms in lower taxonomic levels were present. I attempted to collect at least three representatives of each taxon from each pond for analysis.

Laboratory processing

Shells from snails and wings from large beetles were discarded. Dorsal muscle was dissected from fish and albumen removed from grebe eggs. In cases where organisms were very small, two to three individuals were combined in a sample to ensure sufficient material for analysis. All other organisms were processed whole. Samples were lyophilized for 24 hours and then ground to a fine powder.

After grinding, 1.0 mg (± 0.1 mg) of tissue was weighed into 4x6 mm tin capsules. Sample processing was conducted at the University of Saskatchewan, Department of Soil Science by an ANCA G/S/L elemental analyzer coupled to a Tracer/20 mass spectrometer manufactured by Europa Scientific of Crewe, U.K.

Error associated with both $\delta^{13}C$ and $\delta^{15}N$ measurement was ± 0.2‰ (M. Stocki, personal communication).

Stable isotope composition of a sample is expressed in the δ (delta) notation with values in ‰ (parts per thousand, or per mil), it is based on the following equation:

$$\delta X (‰) = [(R_{sample}/R_{standard})-1] \times 1000 \quad (1)$$

where X is ^{13}C or ^{15}N and R is the ratio of $^{13}C/^{12}C$ or $^{15}N/^{14}N$ for the sample or standard (Peterson and Fry 1987). International standards used in SIA are Pee Dee Belemnite (PDB) formation in South Carolina for carbon (Craig 1957) and atmospheric nitrogen gas for nitrogen (Ehleringer and Rundel 1989).

Baseline corrections

I standardized baseline values of $\delta^{15}N$ of all organisms by subtracting the mean $\delta^{15}N$ value for snails at each pond from the mean $\delta^{15}N$ value of each taxon. This method corrects for inherently variable $\delta^{15}N$ that can be caused by fertilizer runoff in agricultural areas (Cabana and Rasmussen 1996, Cole et al. 2004) or differences in underlying soils (Cheng et al. 1964). This standardization allows for comparison of trophic position between ponds.

Post (2002) examined the use of different long-lived primary consumers as baselines and found that snails are indicative of the base of the littoral food-web, reflecting the isotopic signatures of detritus and periphyton, while mussels are indicative of the base of the pelagic food-web. There is no true pelagic zone in small pond systems and mussels do not inhabit such environments, therefore snails are the most appropriate baseline organism. Snails from the Families

Lymnaeidae, Planorbidae and Physidae were found at ponds and combined, where all taxa within a pond were pooled under the name Gastropoda.

Calculation of trophic positions

Baseline adjusted δ^{15}N values were used to calculate trophic position for each taxon to compare food-web structure of ponds occupied and unoccupied by Horned Grebes (Vander Zanden et al. 1997) using the following equation:

$$\text{Trophic position} = (\text{baseline adjusted } \delta^{15}\text{N}/3.4) + 2 \qquad (2)$$

where 3.4 is the average enrichment of δ^{15}N for an individual over diet, and two is added to account for the trophic position of primary consumers (primary producers are level one).

Invertebrate biomass collection

In July 2007 I conducted standardized sweeps from 13 of 14 SIA ponds (I was unable to sample pond 55). Invertebrate sampling was conducted in July to correspond with timing of egg hatching and feeding of newly hatched young by grebes. I conducted six vertical sweeps at each pond, with a standard D-frame invertebrate dip net, beginning just below the sediment and sweeping vertically upwards through the water column. Three sweeps were collected inshore (within the emergent vegetation, water depth: $\bar{x} \pm$ SE: 26.41 ± 2.63 cm, mean volume of water sampled: 7368 cm^3) and three were collected offshore (outside the emergent vegetation, depth: 68.08 ± 7.06 cm, mean volume sampled: 18993 cm^3). Invertebrates were oven dried for one week and weighed using an analytical balance accurate to 0.01 mg. Biomass values from all six sweeps were pooled prior to analysis, resulting in one total biomass value per pond.

Statistical analysis

Summary statistics and independent samples *t*-tests were performed to compare trophic positions and $\delta^{13}C$ of common taxa between ponds occupied and unoccupied by Horned Grebes. Independent samples *t*-tests were preformed to compare total invertebrate biomass between ponds occupied and unoccupied by Horned Grebes. An independent samples *t*-test was also conducted to compare invertebrate biomass between ponds with and without fish (regardless of species) to determine if the presence of fish had an effect on pond invertebrate biomass. When multiple comparisons were conducted on the same data set, I used the Bonferroni correction to calculate a new α (new $\alpha = 0.05$/number of comparisons; Gotelli and Ellison 2004) to minimize the risk of Type I error.

Results

Consumer $\delta^{13}C$ ranged from -37.94‰ to -19.98‰, and $\delta^{15}N$ ranged from -0.84‰ to 14.45‰ (pre-baseline transformation) in my 14 ponds. Figure 3.2 depicts the baseline transformation for Horned Grebe egg albumen. Baseline transformations effectively decreased the mean and 95% confidence intervals around the mean from 9.74 ± 1.21‰ before transformation to 6.99 ± 0.78‰ after transformation. See Appendix 3.1 for a summary of mean $\delta^{13}C$ and $\delta^{15}N$ (adjusted and unadjusted) of taxa from each pond.

Figures 3.3 and 3.4 present food-webs as $\delta^{15}N$ (adjusted) versus $\delta^{13}C$ bi-plots for ponds with and without Horned Grebes, respectively. Although there was some variability in the taxa collected between ponds, most taxa were common across ponds. Assuming the commonly reported value of 3 – 4‰ $\delta^{15}N$ increase relative to diet (DeNiro and Epstein 1981), and considering the overlapping carbon signatures of certain invertebrate taxa with those of grebes, Horned Grebes appear to be primarily consuming predatory insect larvae (anisopteran and zygopteran nymphs and *Dytiscus* larvae) and leeches.

Table 3.2 presents trophic position calculations and results from independent samples *t*-tests comparing mean trophic positions of common taxa between ponds with and without grebes. There was no difference in the trophic position of any taxon between ponds with and without Horned Grebes.

Table 3.3 summarizes $\delta^{13}C$ values of taxa in ponds with and without breeding grebes. After Bonferroni adjusted α of 0.004, there was no difference in $\delta^{13}C$ for any taxon between ponds with and without grebes. Using the non-adjusted α of 0.05, amphipods ($p = 0.02$) were enriched in ^{13}C (had a higher $\delta^{13}C$) in ponds with grebes.

Figure 3.5 pictures combined values for the same food-webs shown in Fig. 3.3 and Fig. 3.4 presenting overall means (means of pond means) and ranges of $\delta^{13}C$ and $\delta^{15}N$ of different key taxa and invertebrate functional groups. These bi-plots suggest that Horned Grebes are likely consuming the above mentioned predatory invertebrates, as well as some of the detritivores (including amphipods, mayfly larvae, caddisfly larvae, water boatmen) and adult coleopterans (Fig. 3.5).

Horned Grebes were at approximately the same trophic position as brook stickleback when both species were present. Grebes did not appear to consume stickleback to any extent, however, they may have consumed pearl dace in the one pond (36) where this fish was present (Fig. 3.3e).

Invertebrate biomass did not differ between occupied (n = 7, $\bar{x} \pm$ SE: 44.09 ± 9.25 mg, range: 8.65 – 75.81 mg) and unoccupied (n = 6, 140.88 ± 48.03 mg, range: 23.92 – 349.25 mg) ponds ($t_{5.37} = -1.98$, $p = 0.10$) following correction for unequal variances with Levene's test. Invertebrate biomass also did not differ between ponds occupied (76.21 ± 28.22 mg, range: 16.68 – 141.53 mg) and unoccupied (94.34 ± 35.86 mg, range: 8.65 – 349.25 mg) by fish ($t_{11} = -0.31$, $p = 0.76$).

Discussion

Horned Grebes in relation to food-webs

Constructed borrow-pit wetlands in northwestern Alberta have fairly simple food-webs which are consistent from pond to pond. I found no evidence that food-webs or invertebrate biomass of ponds occupied by Horned Grebes differed from those of ponds lacking grebes.

Following food-web sampling in June 2007, chicks were produced on four of the seven occupied ponds (ponds 11, 12, 36, 87). A total of 64.2% of SIA ponds maintained their grebe status between 2007 and 2008 (remaining either occupied or unoccupied by grebes; E. Kuczynski, unpublished data). Three (13, 55, 77) out of the seven ponds where grebes were absent in 2007 were occupied by Horned Grebes in 2008 and two (11, 87) of the seven ponds where grebes were present in 2007 were unoccupied in 2008. This was slightly lower than the landscape average as a whole where 68.5% of 201 ponds retained their status between June 2007 and June 2008 (Chapter 2).

Using the Vander Zanden et al. (1997) model of continuous trophic position, I found that Horned Grebes were top predators, occupying the highest trophic position when present. Although enriched in ^{15}N over both species of fish, Horned Grebes appeared to occupy the same trophic position as brook stickleback, and a higher trophic position than pearl dace. The Red-necked Grebe is also top predator on lakes it occupies in Alberta, regardless of whether or not fish are present (McParland 2004, Paszkowski et al. 2004). Unlike Horned Grebes, Red-necked Grebes occupy a higher trophic position on lakes with fish than fishless lakes (McParland 2004). Horned Grebes are not as piscivorous as Red-necked Grebes during the breeding season, (although Red-necked Grebes also commonly nest on fishless lakes in Alberta; Paszkowski et al. 2004) and thus their tissues are not always greatly enriched in ^{15}N over fish.

The apparent lack of difference in food-web structure between ponds with and without grebes may be explained by the fact that Horned Grebes are generalist predators, feeding on locally abundant taxa, across a variety of trophic positions (termed trophic omnivory). Trophic omnivory is common in small freshwater systems (Post et al. 2000), where preferred prey may not be present at abundances sufficient for diet limitation and thus specialization. Omnivory can also help stabilize food-webs in small lakes, suppressing trophic cascades that would likely occur with a specialist predator in a small system (McCann 2005). McParland (2004) and Paszkowski et al. (2004) found that Red-necked Grebes breeding in Alberta lakes were more flexible in their diets than anticipated, feeding on both invertebrates and fish. Sotiropoulos (2002) also suggested omnivory to be occurring within food-webs of small ponds where Whooping Crane (*Grus americana*) nest in Wood Buffalo National Park, as ^{15}N fractionation between taxa at different trophic levels was smaller than the suggested 3 – 4‰ (as was also seen in my study).

For small wetlands such as the constructed sites studied here, breeding site selection by grebes may not be based on the composition of prey species but overall prey abundance (productivity), or the availability of some minimum amount of prey required to sustain a brood. However, if there was a difference in invertebrate biomass at the time of breeding pond selection in May, it was not detectable in July, an important time for grebe chicks to have access to plentiful resources. Invertebrate biomass in SIA ponds appeared highly variable, and was not affected by the presence of grebes or fish. Among different ponds, individual grebes might differentially choose prey items based on size, nutritional value and ease of capture, which might also fluctuate seasonally among taxa. If individual grebes are making decisions influenced by prey type and availability, patterns in habitat selection based on resource abundance alone would be very difficult to detect.

Although they are generalists, Horned Grebe bill size and shape place natural limits on the size of potential prey items they can consume. The Horned Grebe studied here, *P. auritus cornutus* has a fine bill, which may indicate a narrow range of potential prey and therefore specialization on arthropods rather than fish during the breeding season (Fjeldså 1973a, b). Stomach contents of 49 Horned Grebes from the North Atlantic population (*P. auritus arcticus*) in northern Norway and Iceland contained, in order of abundance, cladocerans, aerial insects, chironomid larvae and pupae, small fish and adult and larval coleopterans (Fjeldså 1973a), however this thicker billed population is more piscivorous and breeds on larger waterbodies than the Eastern European *P. auritus auritus* as well as the North American *P. a. cornutus* (Fjeldså 1973a), although race *P. a. arcticus* is not recognized as a separate subspecies from *P. a. auritus* (Stedman 2000). Stomachs of 57 Horned Grebes caught in Canada contained coleopterans, heteropterans, trichopterans and other insects, in addition to crayfish and fish, although in this study, stomach contents of grebes were not separated seasonally or by fresh or salt water (McAtee and Beal 1912 in Fjeledsa 1973a), and it is possible that many of the occurrences of fish were from wintering birds.

Carbon signatures

Although there were no carbon signature differences for taxa in ponds with and without grebes, most taxa appeared to have slightly higher $\delta^{13}C$ in ponds with grebes. It is possible that the presence of a top predator could force prey taxa into emergent vegetation around pond edges; taxa from littoral zones of lakes have been demonstrated to have enriched carbon isotopic signatures (Vander Zanden and Rasmussen 1999).

The range of values I encountered in my study for $\delta^{13}C$ (-37.94 to -19.98‰) match values reported in the literature for attached algae (ranging from approximately -40 to -20‰; France 1995a, Keough et al. 1998), and detritus (-30 to -25‰; Finlay 2001), and somewhat for phytoplankton (ranging from -45‰ to -

20‰ but on average below -30‰; France 1995b). However, they were generally lower than values reported for aquatic macrophytes (ranging between -30 and -8‰; France 1995a). France (1995a) presented evidence that $\delta^{13}C$ values for aquatic animals are more similar to those of attached algae and detritus than to macrophytes, which appear to play a small role in aquatic food-webs. This suggests that the food-webs of ponds described here were based on periphyton or detritus; McParland (2004) found similar results with shallow lakes occupied by Red-necked Grebes.

From albumen $\delta^{13}C$ and $\delta^{15}N$ values, it appears that female Horned Grebes use nutrients derived from breeding ponds to produce eggs (Fig. 3.2). Eggs derived from nutrients acquired from coastal wintering areas would be higher in both $\delta^{13}C$ and $\delta^{15}N$ relative to eggs derived from freshwater sources (Hobson et al. 2000). Similarly, research with Red-necked Grebes in Alberta found that although muscle tissue and feathers of adult grebes reflected signatures of the wintering grounds, egg tissues (albumen and yolk), as well as chick muscle, reflected signatures of breeding lakes, indicating that local resources were important in egg formation (McParland 2004, Paszkowski et al. 2004).

Other food-web members

In this study, no attempt was made to construct complete food-webs of ponds, rather I compared common taxa that grebes might consume across ponds, and chose taxa that represented a range of trophic positions. Because in some ponds grebe egg albumen was greater than 3 – 4‰ higher than all collected taxa, it is possible that at those sites I either failed to collect large leeches or predatory larvae, or grebes were consuming some other unsampled taxon that elevated their δ^{15}N. For instance, terrestrial insects were not sampled in my study, but they have been found in the stomach contents of Red-necked Grebes in Alberta (Paszkowski et al. 2004) as well as the North Atlantic Horned Grebe population (Fjeldså 1973a), likely picked off the waters surface or emergent vegetation.

Although fish were present in four out of the 14 ponds, fish are likely rare in constructed wetland systems. An additional 15 ponds were checked for fish in July 2007 and only one had fish (E. Kuczynski, unpublished data). Pond 94 (Fig. 3.3d) is located next to a natural wetland; fish likely entered the constructed wetland during periods of high water. It is also possible for fish to enter a system through stocking or through translocation by birds. Many studies have found that fish negatively affect birds on ponds; Horned Grebes in Europe may avoid ponds with fish (Cramp and Simmons 1977). The presence of fish can greatly alter invertebrate communities, affecting abundance (Zimmer et al. 2001), biomass (Hornung and Foote 2006), and general composition (McParland and Paszkowski 2006). However, fish presence did not affect invertebrate biomass detectably in my study. It may have affected invertebrate composition in pond 36 (Fig. 3.2e); this pond contained pearl dace and rainbow trout, and likely had the greatest abundance of fish (although this was not quantified). In this pond, I found it difficult to sample invertebrates in sufficient quantities for analysis (biomass was also lowest, at 16.68 mg), and I found taxa such as mites and beetles (*Liodessus affinis* and *Hydroporus superioris*) that did not occur in other sites.

Food-web shifts

In a study where a top predator, northern pike (*Exos lucius*), was introduced into a previously fishless Alberta lake, pike reduced the abundance and biomass of large invertebrate taxa, such as odonates and leeches (Venturelli and Tonn 2005). These changes would likely be reflected in calculated trophic positions. Sotiropoulos (2002) also suggested that a structural difference existed between food-webs of ponds occupied and unoccupied by fish in Wood Buffalo National Park. Although the addition of a top predator can alter trophic positions of other food-web members, I found no evidence that the Horned Grebe triggered trophic shifts.

I detected no difference between food-webs of ponds with and without grebes; however I am unable to distinguish between three alternative interpretations of this pattern. 1) The lack of difference indicates that Horned Grebes are generalists, and thus do not cause shifts in trophic positions of their prey; food-webs of all ponds are essentially identical as far as a grebe is concerned. 2) There is, or was at the time of selection by breeding grebes, an inherent difference among ponds that I failed to detect, because following selection and predation by grebes, food-webs of occupied ponds became more similar to food-webs of unoccupied ponds. 3) Horned Grebes are not generalist predators as I suspect, but selective foragers; however, their effects on pond food-webs are relatively small and I could not detect these changes via my limited sampling of sites and prey taxa. More detailed data on the food base of ponds are needed to distinguish between these alternatives, such as measuring invertebrate community structure and biomass before and after grebe selection of an ‘occupied’ pond relative to control ponds which were not selected by grebes (a before-after-control-impact design). It is also possible that individual birds may select ponds via other mechanisms, such as those described in Chapter 2. There is also one additional explanation, based on grebe behaviour: Horned Grebes exhibit nesting or natal site philopatry, returning to sites year after year even if neighboring ponds are equally suitable or better. There is some evidence for philopatry in the literature based on a study that individually marked Horned Grebes (Ferguson 1981).

Conclusions

Although Horned Grebes frequently breed on constructed ponds in northwestern Alberta and they are present on only about one-third of the ponds, the reason they select some ponds over others was not deducible from stable isotope analysis of pond food-webs. I found little pond to pond variation in food-web structure. Horned Grebe females appear to use nutrients derived from breeding ponds to produce eggs. Grebes occupy the highest trophic position on all ponds where present, but do not necessarily consume fish but instead feed on a variety of aquatic invertebrates. My study suggests that borrow-pits provide appropriate summer habitat for Horned Grebes in Alberta.

Literature Cited

Arnold T. W. 1990. Determinacy of clutch size in Horned and Pied-billed Grebes. The Wilson Bulletin **102**:336-338.

Bethke R. W., and T. D. Nudds. 1995. Effects of climate change and land use on duck abundance in Canadian prairie-parklands. Ecological Applications **5**:588-600.

Cabana G., and J. B. Rasmussen. 1996. Comparison of aquatic food chains using nitrogen isotopes. Proceedings of the National Academy of Sciences of the United States of America **93**:10844-10847.

Carlson R. E. 1977. A trophic state index for lakes. Limnology and Oceanography **22**:361-369.

Cheng H. H., J. M. Bremner, and A. P. Edwards. 1964. Variations of nitrogen-15 abundance in soils. Science **146**:1574-1575.

Cody M. L. 1981. Habitat selection in birds: the roles of vegetation structure, competitors, and productivity. BioScience **31**:107-113.

Cole M. L., I. Valiela, K. D. Kroeger, G. L. Tomasky, J. Cebrian, C. Wigand, R. A. McKinney, S. P. Grady, and M. H. Carvalho da Silva. 2004. Assessment of a d15N isotopic method to indicate anthropogenic eutrophication in aquatic ecosystems. Journal of Environmental Quality **33**:124-132.

Craig H. 1957. Isotopic standards for carbon and oxygen and correction factors for mass-spectrometric analysis of carbon dioxide. Geochimica et Cosmochimica Acta **12**:133-149.

Cramp S. C., and K. E. L. Simmons. 1977. Handbook of the birds of Europe the Middle East and North Africa: The birds of the western Palearctic. **1**:722.

DeNiro M. J., and S. Epstein. 1978. Influence of diet on the distribution of carbon isotopes in animals. Geochimica et Cosmochimica Acta **42**:495-506.

DeNiro M. J., and S. Epstein. 1981. Influence of diet on the distribution of nitrogen isotopes in animals. Geochimica et Cosmochimica Acta **45**:341-351.

Downes C. M., and B. T. Collins. 2008. Canadian Bird Trends web site Version 2.2. Canadian Wildlife Service, Environment Canada, Gatineau, Quebec, K1A 0H3.

Ehleringer J. R., and P. W. Rundel. 1989. Stable isotopes: history, units and instrumentation. Pages 1-16 *In* P. W. Rundel, J. R. Rundel, and K. A. Nagy, editors. Stable isotopes in ecological research, Springer-Verlag, New York.

Ferguson R. S. 1981. Territorial attachment and mate fidelity by Horned Grebes. The Wilson Bulletin **93**:560-561.

Finlay J. C. 2001. Stable-carbon-isotope ratios of river biota: implications for energy flow in lotic food webs. Ecology **82**:1052-1064.

Fjeldså J. 1973a. Feeding and habitat selection of the Horned Grebe, *Podiceps auritus* (Aves), in the breeding season. Vidensk Medd Dan Naturhist Foren **136**:57-95.

Fjeldså J. 1973b. Distribution and geographical variation of the Horned Grebe *Podiceps auritus* (Linnaeus, 1758). Ornis Scand **4**:55-86.

Fournier M. A., and J. E. Hines. 1999. Breeding ecology of the Horned Grebe (*Podiceps auritus*) in subarctic wetlands. Canadian Wildlife Service. Occasional paper 99.

France R. L. 1995a. Stable isotopic survey of the role of macrophytes in the carbon flow of aquatic foodwebs. Plant Ecology **124**:67-72.

France R. L. 1995b. Carbon-13 enrichment in benthic compared to planktonic algae: food-web implications. Marine Ecology Progress Series **124**:307-312.

Gingras B. A., and G. Beyersbergen. 2003. Horned Grebe use of artificial ponds in forested and agricultural areas of northwestern Alberta. Poster presentation, Society of Canadian Ornithologists.

Gotelli N. J., and A. M. Ellison. 2004. A primer of ecological statistics. Sinauer Associates, Inc. Publishers, Sunderland, Massachusetts, U.S.A.

Hobson K. A. 1995. Reconstructing avian diets using stable-carbon and nitrogen isotope analysis of egg components: patterns of isotopic fractionation and turnover. The Condor **97**:752-762.

Hobson K. A., K. D. Hughes, and P. J. Ewins. 1997. Using stable-isotope analysis to identify endogenous and exogenous sources of nutrients in eggs of migratory birds: applications to Great Lakes contaminants research. The Auk **114**:467-478.

Hobson K. A., J. Sirois, and M. L. Gloutney. 2000. Tracing nutrient allocation to reproduction with stable isotopes: a preliminary investigation using colonial waterbirds of Great Slave Lake. The Auk **117**:760-774.

Hornung J. P., and A. L. Foote. 2006. Aquatic invertebrate responses to fish presence and vegetation complexity in western boreal wetlands, with implications for waterbird productivity. Wetlands **26**:1-12.

Kelly J. F. 2000. Stable isotopes of carbon and nitrogen in the study of avian and mammalian trophic ecology. Canadian Journal of Zoology **78**:1-27.

Keough J. R. 1998. $d^{13}C$ composition of primary producers and role of detritus in a freshwater coastal ecosystem. Limnology and Oceanography **43**:734-740.

McAtee W. L., and F. E. L. Beal. 1912. Some common game, aquatic and rapacious birds in relation to man. U.S. Department of Agriculture Farmers Bulletin **497**.

McCann K. S., J. B. Rasmussen, J. Umbanhowar, and J. Chase. 2005. The dynamics of spatially coupled food webs. Ecology Letters **8**:513-523.

McParland C. E. 2004. Food web interactions of waterbirds and fish in eutrophic wetlands of Alberta's Aspen Parkland. Ph.D. thesis, University of Alberta, Edmonton, Alberta, Canada.

McParland C. E., and C. A. Paszkowski. 2006. Effects of small-bodied fish on invertebrate prey and foraging patterns of waterbirds in Aspen Parkland wetlands. Hydrobiologia **567**:43-55.

Mitsch W. J., and J. G. Gosselink. 2000. Wetlands. John Wiley & Sons, New York.

Pace M. L., J. J. Cole, S. R. Carpenter, and J. F. Kitchell. 1999. Trophic cascades revealed in diverse ecosystems. Trends in Ecology & Evolution, **14**:483-488.

Paszkowski C. A., B. A. Gingras, K. Wilcox, P. H. Klatt, and W. M. Tonn. 2004. Trophic relations of the Red-necked Grebe on lakes in the western boreal forest: a stable-isotope analysis. The Condor **106**:638-651.

Peterson B. J., and B. Fry. 1987. Stable isotopes in ecosystem studies. Annual Review of Ecology and Systematics **18**:293-320.

Post D. M. 2002. Using stable isotopes to estimate trophic position: models, methods, and assumptions. Ecology **83**:703-718.

Post D. M., M. L. Pace, and N. G. J. Hairston. 2000. Ecosystem size determines food-chain length in lakes. Nature **405**:1047-1049.

Sotiropoulos M. A. 2002. Analysis of pond food webs in the whooping crane nesting area, Wood Buffalo National Park, M.Sc. thesis, University of Alberta, Edmonton, Alberta, Canada.

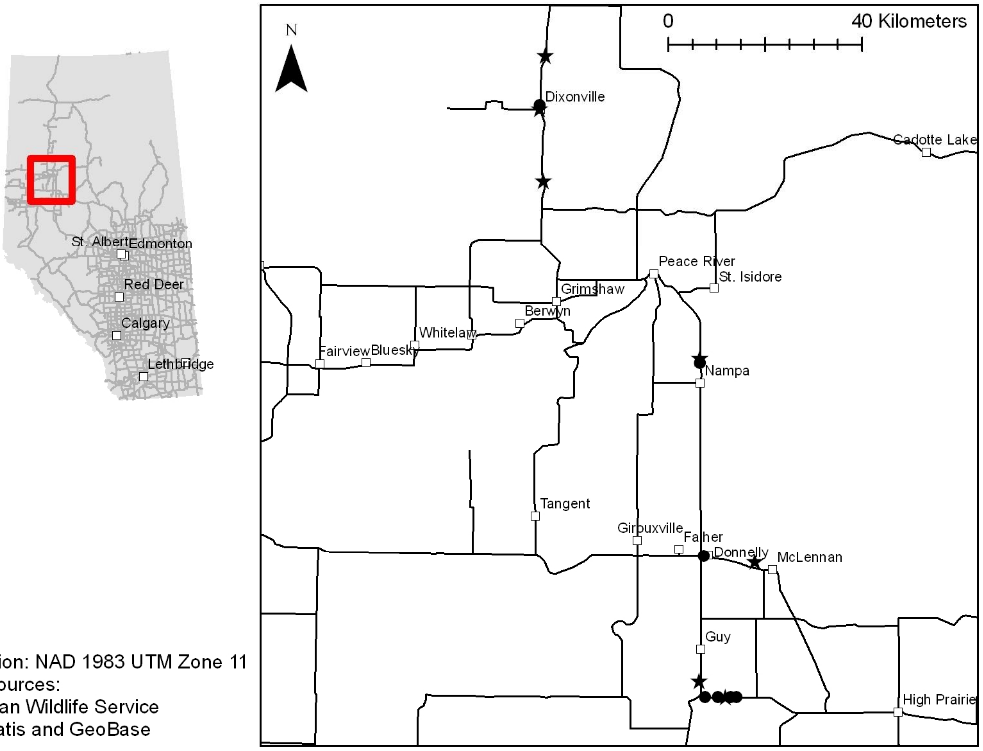
Stedman S. J. 2000. Horned Grebe (*Podiceps auritus*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/505, DOI:10.2173/bna.505.

Vander Zanden M. J., G. Cabana, and J. B. Rasmussen. 1997. Comparing trophic position of freshwater fish calculated using stable nitrogen isotope ratios (δ15N) and literature dietary data. Canadian Journal of Fisheries and Aquatic Sciences **54**:1142-1158.

Vander Zanden M. J., and J. B. Rasmussen. 1999. Primary consumer δ13C and δ15N and the trophic position of aquatic consumers. Ecology **80**:1395-1404.

Venturelli P. A., and W. M. Tonn. 2005. Invertivory by northern pike (*Esox lucius*) structures communities of littoral macroinvertebrates in small boreal lakes. The North American Benthological Society **24**:904-918.

Zimmer K. D., M. A. Hanson, and M. G. Butler. 2001. Effects of fathead minnow colonization and removal on a Prairie wetland ecosystem. Ecosystems **4**:346-357.



Projection: NAD 1983 UTM Zone 11
Data Sources:
Canadian Wildlife Service
GeoGratis and GeoBase

Figure 3.1: Study area map depicting location of borrow-pit ponds, occupied (n = 7; circles) and unoccupied (n = 7; stars) by Horned Grebes that were sampled for SIA in the Peace Parkland, Alberta.

Table 3.1: Summary of physical and chemical characteristics of 14 ponds in the Peace Parkland, Alberta sampled for SIA and total invertebrate biomass based on six standardized sweeps at each pond (see text). Trophic state determined using TP after Carlson (1977).

Pond number	Grebes present or absent	Land-cover	TN (µg/L)	TP (µg/L)	Chl-a (µg/L)	Trophic state according to TP	Conductivity (µS)	pH	Depth (m)	Secchi depth (m)	Area (ha)
13	absent	agriculture	881.00	23.00	0.27	Mesotrophic	1015.00	7.90	4.15	3.25	0.64
21	absent	agriculture	1030.00	78.00	3.86	Eutrophic	1775.00	8.20	4.65	1.90	0.31
50	absent	agriculture	1240.00	59.00	14.30	Eutrophic	505.00	7.85	4.05	0.95	0.54
55	absent	agriculture	*2470.00	*231.00	*33.22	Hypereutrophic	*190.00	*7.65	N/A	N/A	0.30
86	absent	agriculture	796.00	118.00	5.02	Hypereutrophic	1415.00	7.50	2.60	2.45	0.14
77	absent	forest	1070.00	25.00	0.62	Eutrophic	1535.00	8.30	3.70	N/A	0.83
94	absent	forest	1240.00	40.00	7.51	Eutrophic	270.00	7.20	3.15	0.85	0.43
15	present	agriculture	976.00	48.00	7.33	Eutrophic	835.00	8.60	3.80	1.90	0.59
17	present	agriculture	1260.00	26.00	1.51	Eutrophic	1575.00	8.30	3.70	2.23	0.87
341	present	agriculture	1830.00	100.00	2.95	Hypereutrophic	1195.00	10.40	0.75	N/A	0.30
11	present	agriculture	2170.00	51.00	26.23	Eutrophic	275.00	8.95	5.50	0.90	0.45
12	present	agriculture	1390.00	33.00	2.74	Eutrophic	835.00	7.90	2.50	0.78	0.52
36	present	agriculture	1740.00	86.00	13.78	Eutrophic	1035.00	7.90	3.10	0.73	0.54
87	present	agriculture	1160.00	24.00	4.37	Mesotrophic	760.00	9.35	1.85	N/A	0.70

*Water chemistry data for pond 55 collected in June 2008

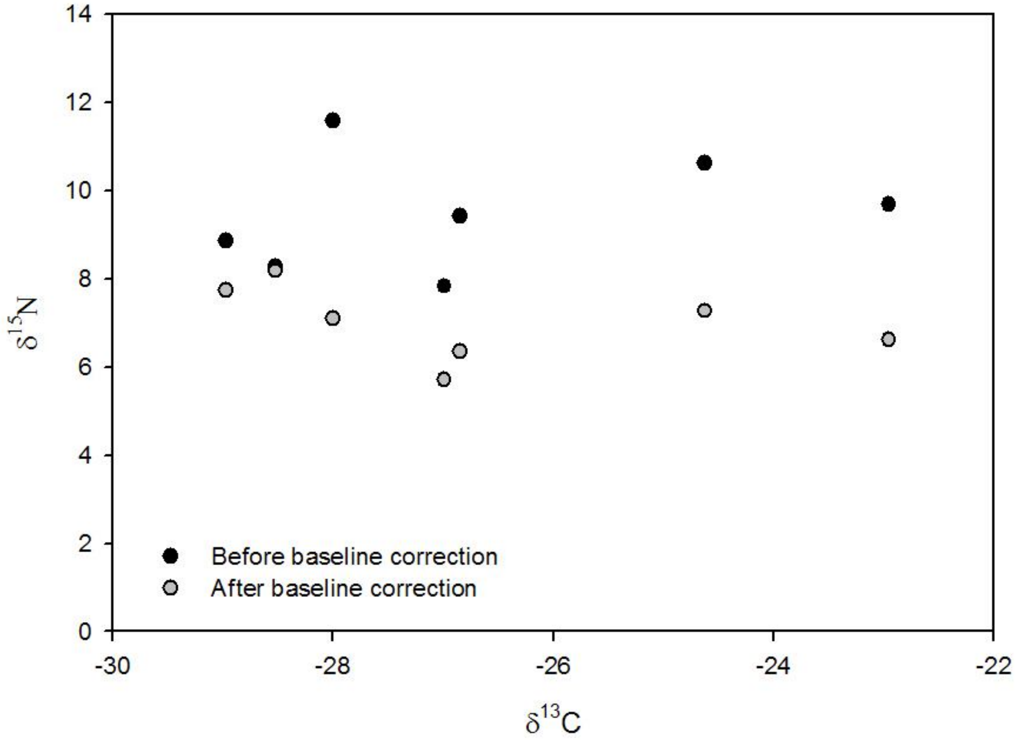
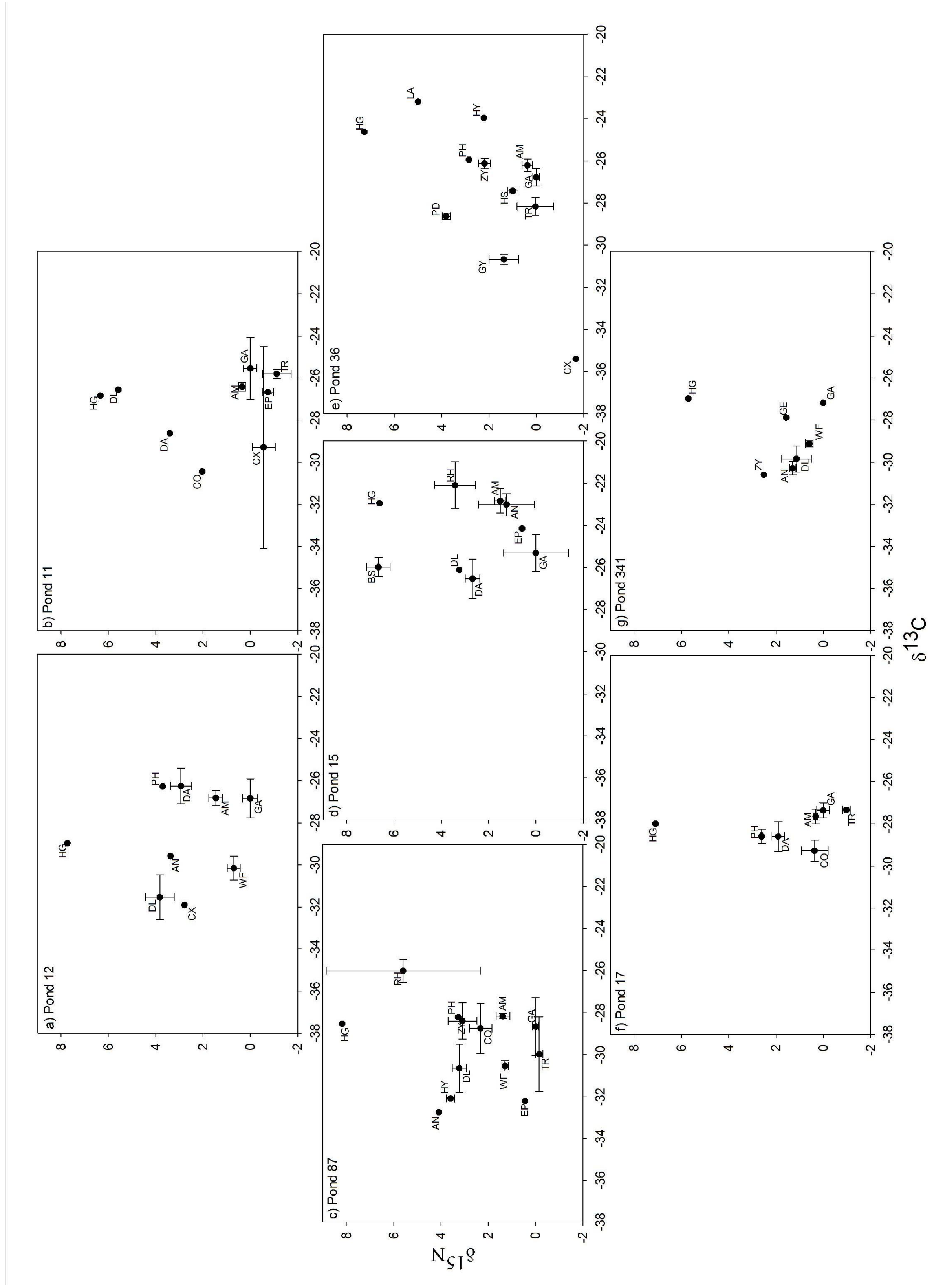
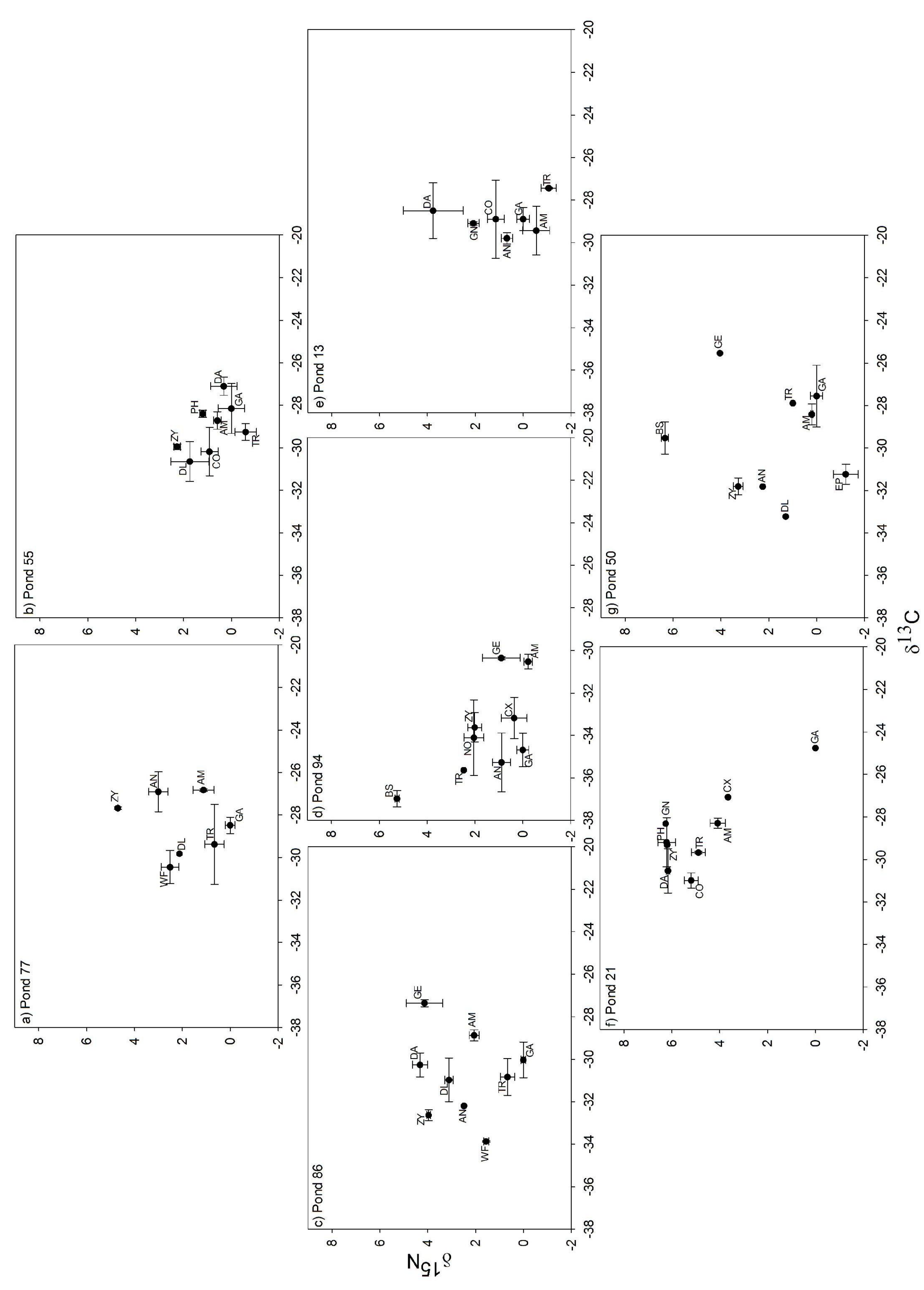


Figure 3.2: Horned Grebe egg albumen from seven constructed wetlands before and after baseline transformation of $\delta^{15}N$.



a) Pond 12
b) Pond 11
c) Pond 87
d) Pond 15
e) Pond 36
f) Pond 17
g) Pond 341
HG
DL
CX
AN
WF
PH
DA
AM
GA
CO
EP
TR
RH
HY
ZY
BS
LA
PD
HS
GY
GE
δ15N
δ13C
8
6
4
2
0
-2
-38
-36
-34
-32
-30
-28
-26
-24
-22
-20


a) Pond 77
ZY
AN
AM
DL
WF
TR
GA
b) Pond 55
DA
PH
GA
AM
ZY
TR
CO
DL
c) Pond 86
GE
AM
DA
DL
TR
GA
ZY
AN
WF
d) Pond 94
BS
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NO
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f) Pond 21
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δ13C
8
6
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2
0
-2
-38
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-34
-32
-30
-28
-26
-24
-22
-20

Figure 3.3 a-g: Baseline-adjusted $\delta^{15}N - \delta^{13}C$ bi-plots for seven constructed wetlands in the Peace Parkland, Alberta that supported breeding Horned Grebes in summer 2007. Filled circles are taxon means, representing combination of one to three individuals per taxon, and bars depict standard error. See Table 3.2 for abbreviations.

Figure 3.4 a-g: Baseline-adjusted $\delta^{15}N - \delta^{13}C$ bi-plots for seven constructed wetlands in the Peace Parkland, Alberta that lacked Horned Grebes in summer 2007. Filled circles are taxon means, representing combination of one to three individuals per taxon, and bars depict standard error. See Table 3.2 for abbreviations.

Table 3.2: Summary of taxa used in SIA, the number of ponds in which each taxon was found, the number of individuals used from each pond and the mean trophic position (TP, calculated using equation 2) and standard error, grouped by ponds with and without breeding Horned Grebes. Mean difference and P value are associated with *t*-tests conducted between common taxa in ponds with and without Horned Grebes (see text). The Bonferroni-adjusted level of significance is $\alpha = 0.004$. Abbreviations are used in Figures 3.3 and 3.4.

		Ponds with Horned Grebes			**Ponds without Horned Grebes**				
Taxa	**Code**	**n ponds**	**n individuals**	**Mean TP ± SE**	**n ponds**	**n individuals**	**Mean TP ± SE**	**Mean difference**	**P value**
Amphipoda - Gammaridae	AM	6	18	2.26 ± 0.07	7	20	2.30 ± 0.18	-0.04	0.85
Brook stickleback	BS	1	2	3.96	2	6	3.70 ± 0.16	0.25	0.53
Coleoptera - *Colymbetes* sp.	CO	3	7	2.46 ± 0.18	3	9	2.71 ± 0.41	-0.25	0.61
Coleoptera - *Dytiscus* - larval	DL	5	10	3.00 ± 0.21	4	7	2.61 ± 0.11	0.39	0.17
Coleoptera - *Dytiscus* adult	DA	4	10	2.80 ± 0.09	4	10	3.07 ± 0.36	-0.27	0.50
Coleoptera - Gyrinidae	GY	1	3	2.40					
Coleoptera - *Hydroporus superioris*	HS	1	3	2.29					
Dytiscidae - *Liodessus affinis*	LA	1	1	3.47					
Ephemeroptera	EP	3	4	2.03 ± 0.12	1	2	1.64	0.39	0.26
Gastropoda	GA	7	19	2.00	7	19	2.00		
Hemiptera - Corixidae	CX	3	5	2.05 ± 0.39	2	4	2.59 ± 0.48	-0.54	0.45
Hemiptera - Gerridae	GE	1	1	2.46	3	6	2.89 ± 0.31	-0.43	0.57
Hemiptera - Notonectidae	NO				1	2	2.60		
Hirudinea - Gnathobdellida	GN				2	4	3.23 ± 0.61		
Hirudinea - Pharyngobdellida	PH	4	6	2.91 ± 0.07	2	5	3.09 ± 0.74	-0.18	0.85
Hirudinea - Rhynchobdellida	RH	2	5	3.33 ± 0.32					
Horned Grebe egg albumen	HG	7	7	4.06 ± 0.09					
Hydrachnidia	HY	2	3	2.85 ± 0.20					
Odonata - Anisoptera	AN	4	7	2.73 ± 0.21	5	11	2.55 ± 0.13	0.19	0.46
Odonata - Zygoptera	ZY	3	7	2.76 ± 0.08	6	13	3.10 ± 0.19	-0.33	0.28
Pearl dace	PD	1	2	3.12					
Trichoptera	TR	4	11	1.84 ± 0.09	7	15	2.34 ± 0.22	-0.50	0.14
Wood frog tadpole	WF	3	9	2.25 ± 0.06	2	6	2.60 ± 0.14	-0.35	0.08

Table 3.3: Summary of taxa used in SIA, the number of ponds in which each taxon was found, the number of individuals used from each pond and mean $\delta^{13}C$ and standard error, grouped by ponds with and without breeding Horned Grebes. Mean difference and P value are associated with t-tests conducted between common taxa in ponds with and without Horned Grebes (see text). Significance level is adjusted using the Bonferroni adjustment, $\alpha = 0.0038$.

	Ponds with Horned Grebes			Ponds without Horned Grebes				
Taxa	**n ponds**	**n individuals**	**Mean $\delta^{13}C \pm SE$**	**n ponds**	**n individuals**	**Mean $\delta^{13}C \pm SE$**	**Mean difference**	**P value**
Amphipoda - Gammaridae	6	18	-26.35 ± 0.77	7	20	-28.73 ± 0.43	2.38	0.02
Brook stickleback	1	2	-26.00	2	6	-33.26 ± 3.72	7.26	0.46
Coleoptera - *Colymbetes* sp.	3	7	-29.48 ± 0.50	3	9	-30.02 ± 0.61	0.54	0.53
Coleoptera - *Dytiscus* - larval	5	10	-28.94 ± 1.10	4	7	-31.17 ± 0.73	2.23	0.16
Coleoptera - *Dytiscus* adult	4	10	-27.51 ± 0.64	4	10	-29.10 ± 0.80	1.59	0.17
Coleoptera - Gyrinidae	1	3	-30.68					
Coleoptera - *Hydroporus superioris*	1	3	-27.44					
Dytiscidae - *Liodessus affinis*	1	1	-23.19					
Ephemeroptera	3	4	-27.67 ± 2.37	1	2	-31.24	3.58	0.53
Gastropoda	7	19	-26.81 ± 0.43	7	19	-28.94 ± 1.14	2.13	0.11
Hemiptera - Corixidae	3	5	-32.19 ± 1.77	2	4	-30.13 ± 3.05	-2.06	0.57
Hemiptera - Gerridae	1	1	-27.88	3	6	-27.75 ± 1.41	0.13	0.97
Hemiptera - Notonectidae				1	2	-34.11		
Hirudinea - Gnathobdellida				2	4	-28.71 ± 0.39		
Hirudinea - Pharyngobdellida	4	6	-27.26 ± 0.67	2	5	-28.80 ± 0.40	1.54	0.12
Hirudinea - Rhynchobdellida	2	5	-24.05 ± 1.96					
Horned Grebe egg albumen	7	7	-26.70 ± 0.83					
Hydrachnidia	2	3	-28.02 ± 4.05					
Odonata - Anisoptera	4	7	-28.90 ± 2.08	5	11	-31.20 ± 1.38	2.30	0.37
Odonata - Zygoptera	3	7	-28.37 ± 1.29	6	13	-30.83 ± 0.91	2.47	0.16
Pearl dace	1	2	-28.64					
Trichoptera	4	11	-27.82 ± 0.87	7	15	-30.02 ± 1.03	2.20	0.18
Wood frog tadpole	3	9	-29.93 ± 0.42	2	6	-32.16 ± 1.71	2.23	0.41

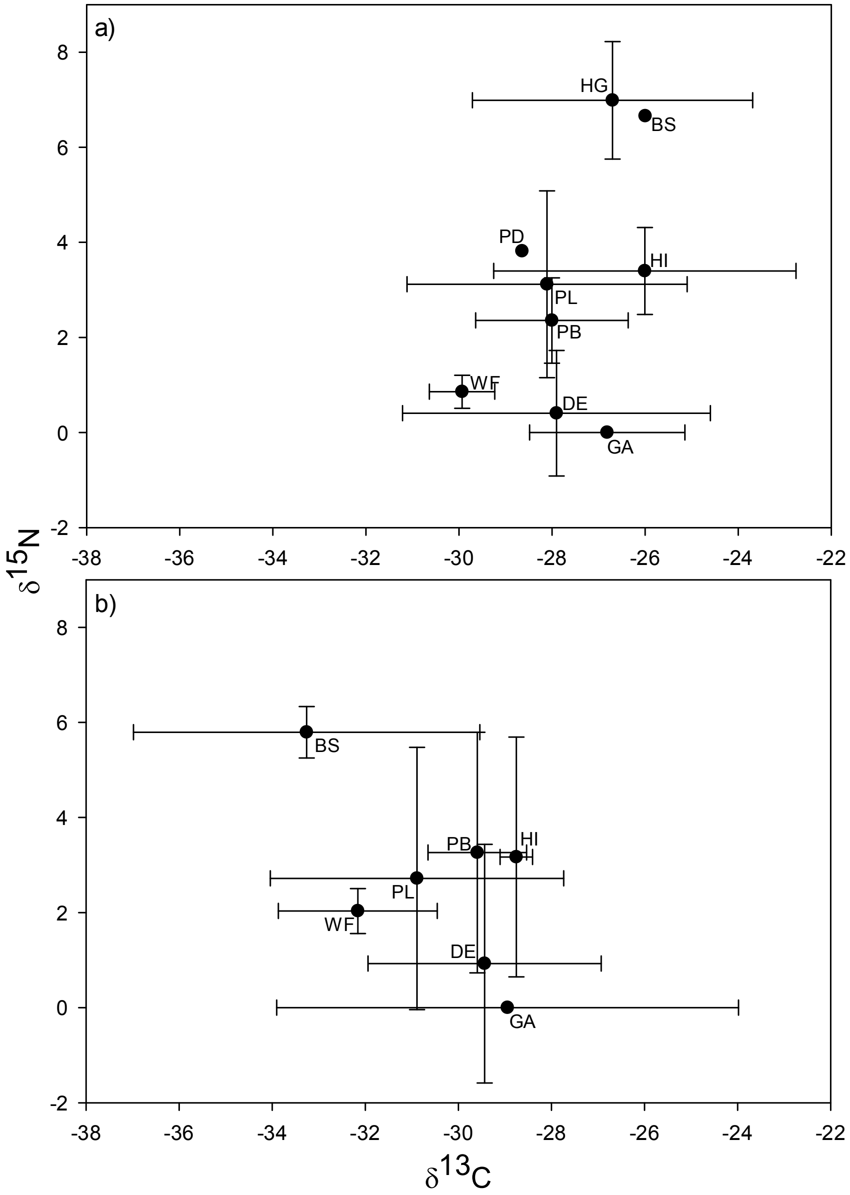


Figure 3.5: Summary of food-webs for ponds in which Horned Grebes were a) present, and b) absent. Circles represent the mean of means from 1 – 7 ponds where key taxa were present or mean values for functional groups and bars depict the range of $\delta^{13}C$ and $\delta^{15}N$ values associated with taxa in that group. HG = Horned Grebe egg albumen, BS = brook stickleback, PD = pearl dace, HI = Hirudinea (Rhynchobdellida, Pharyngobdellida, Gnathobdellida), PL = predaceous larvae (Anisoptera, Zygoptera, Dytiscus larvae), PB = predaceous beetles (Dytiscus adults, Colymbetes), WF = wood frog tadpole, DE = detritivores (Amphipoda, Ephemeroptera, Trichoptera, Corixidae), GA = Gastropoda.

Chapter 4

Bird assemblages on constructed wetlands

Introduction

The Peace Parkland of northwestern Alberta, Canada is an important breeding area and flyway for many species of aquatic birds (Beyersbergen et al. 2004). Historically the landscape was a mosaic of Boreal Mixed-wood Forest and Aspen Parkland. It has been greatly modified through forestry and the energy sector, but particularly by agriculture. Since the 1950s, agricultural expansion in western Canada, and particularly in Alberta, has caused declines in breeding waterfowl populations (Bethke and Nudds 1995). With the expansion of agriculture, as well as industry, comes road construction, and in northwestern Alberta borrow-pits are excavated to collect soil for road beds. These pits form uniform rectangular ponds, and are located along the highways that run through the parkland and boreal forest of northwestern Alberta.

Borrow-pits may be of use to aquatic birds for several purposes. They may function as temporary resting and refueling stops in the spring and fall for birds en route to more northerly breeding areas or southerly wintering areas. Birds may also settle and breed on them. Drought conditions can negatively affect aquatic bird breeding habitat, and it is likely that migrating birds will search for deeper, more permanent wetlands when preferred habitat is non-existent in dry years, for example, on the prairies (Austin 2002); borrow-pits may meet their needs.

Habitat needs of aquatic birds vary depending on a species' locomotion and foraging strategies. Dabbling ducks, such as Mallard (*Anas platyrhynchos*), will move broods an average of 200 m over land to find feeding ponds (Dzus and Clark 1997), so it is not crucial to have good nesting and foraging resources at the same wetland. Mallard broods will also use multiple wetlands in the first few weeks of life (Dzus and Clark 1997). Nesting grebes and American Coots (*Fulica americana*) rely exclusively on within pond resources both for breeding and foraging. Diving ducks, such as Lesser Scaup (*Aythya affinis*) and Bufflehead (*Bucephala albeola*), exhibit foraging and nesting behaviour intermediate between dabblers and grebes; these ducks use fewer wetlands during the breeding season but are not limited to one site (Elmberg et al. 1994). Resources required by a species could include specific types and structures of vegetation within a site, important both as food for some species, and nesting materials for others. General land-cover features, such as whether a pond is located in agricultural or forested upland, may be important in breeding habitat selection. Species found in northwestern Alberta are adapted to breed in forest, parkland, or grassland, possibly as a consequence of where they nest. Dabbling ducks such as Mallard and teal create their nests upland of waterbodies, using grasses and forbs for nesting material, and are thus are well adapted for nesting in prairie and open parkland. Bufflehead and goldeneye, however, require tree snags for nesting, which are more common in continuous forest. Because birds such as the Horned Grebe (*Podiceps auritus*) and American Coot create floating nests on the water, upland habitat type may not be important for these species when they select breeding ponds.

Many studies have examined species-area relationships for aquatic bird communities (Brown and Dinsmore 1986, Elmberg et al. 1994, Paszkowski and Tonn 2000, Paracuellos and Telleria 2004, McParland and Paszkowski 2007). However, borrow-pits were constructed for a common purpose, and are thus more uniform in morphometry. This allows for the study of bird assemblages and the variables that influence their habitat use while controlling for wetland size.

In this study I ask the following questions: 1) what aquatic birds are using constructed borrow-pit ponds in northwestern Alberta, and are patterns of occurrence and richness consistent throughout the summer? Borrow-pits are a common source of water on the landscape and could potentially be important for breeding birds. 2) What local pond and larger landscape characteristics are correlated with occurrence of different species of aquatic birds, and do certain repeatable assemblages of birds occur on ponds in different land-cover types (ranging from forest to agriculture)? and, 3) Is there a seasonal shift in patterns of pond use by aquatic birds, from spring (May) to summer (late June) reflecting less predictable use during migration and more focused habitat selection during breeding?

Methods

Surveys

Two-hundred borrow-pits were surveyed monthly during May, June, July and August 2007. Survey methods for aquatic birds were the same as used for

Horned Grebes in Chapter 2. All non-passerine aquatic birds observed on the water's surface or on the shoreline were recorded and all non-passerine birds heard but not directly observed (e.g. Sora, *Porzana carolinus*) were also recorded. Birds flying over a pond were only recorded if they landed on or took-off from the pond. The number of adults and chicks present were recorded for each species on a pond; however, due to the secretive nature of chicks, only numbers of adult birds were used for quantitative analyses.

Environmental variables

For all ponds, surface area and distance from the road were estimated in May with a digital rangefinder. Percent of emergent and riparian vegetation covering the periphery of the pond, as well as the percent of pond surface area covered by emergent vegetation (a measure of the width of this vegetative zone), were estimated visually, and recorded in August. I used Bayley and Prather's (2003) rank method (1-5) to estimate the amount of submersed aquatic vegetation (SAV) within each pond in July (see Chapter 2). I also recorded whether beaver (*Castor canadensis*) activity was visible at the pond site, either within a pond (presence of a beaver and/or lodge), or immediately surrounding the pond (downed trees with beaver markings). Evidence of human activity was recorded at each pond (as either presence or absence). Human activity included the presence of a human structure directly within a pond, such as a bubbler, pump, or dock.

I used UTM northing for each pond in analyses as a measure of the north-south gradient of the study area. I used a combination of digitized air photos and images from Google Earth (Google Earth 4.2.0205.5730) in ArcGIS Version 9.2 (ESRI 2007) to calculate the proportions of dominant land-covers within 500 m and 1 km buffer areas around each pond (described in detail in Chapter 2). Although five land-cover categories were delineated, agriculture (row crop production, hay production, pasture) and forest were the dominant land-cover types in the Peace Parkland and were used in initial analysis. Mensing et al. (1998) found that wetland-associated birds respond to relatively small (500 m and 1 km) landscape scales. However, as the proportions of forest within both sizes of buffer were highly correlated (Spearman's rho = 0.952, $p < 0.001$), as were the proportions of agriculture (Spearman's rho = 0.941, $p = 0.001$), only data from the 500 m buffer were used in final analyses to characterize terrestrial habitat most closely associated with each pond. Similarly, as the proportion of agriculture and proportion of forest within the 500 m buffer were highly correlated (Spearman's rho = -0.932, $p < 0.0001$), only proportion of forest was used in analyses. All ponds had some forest within their buffers, while many heavily forested ponds had no agriculture. For analysis, ponds were divided into three groups based on the proportion of forest within the 500 m buffer zone: 0-33.3% forest (hereafter referred to as 'agriculture', n = 91 ponds), 33.4-66.6% forest ('mixed', n = 44) and 66.7-100% forest ('forest', n = 65) to capture areas with little forest (high levels of agriculture), areas with a mix of forest and agriculture, and areas that were primarily forested. Proportion of water (pooled from constructed and natural sources) within each 500 m buffer was also used as a variable in analyses, in addition to the straight-line distance from the edge of each pond to the edge of the nearest water body (either natural or constructed).

Statistical Analyses

Data analysis was conducted with SPSS 16.0 for Windows (SPSS Inc. Chicago, IL USA), SigmaPlot 10.0 and PC-ORD 5.0 for Windows (McCune and Mefford 1999). A significance level of $\alpha = 0.05$ was used for all analyses unless otherwise stated. When multiple comparisons were necessary with Wilcoxon, Mann Whitney U, McNemar and MRPP tests, the Bonferroni correction was used to calculate an adjusted α (new $\alpha = 0.05$/number of comparisons; Gotelli and Ellison 2004).

Pond size and species richness comparisons

To determine whether borrow-pits are indeed uniform in size across land-cover types, I conducted a one-way ANOVA followed by Tukey HSD post-hoc tests; analysis of pond area was conducted on square-root transformed data to meet the assumption of normality.

To assess whether species richness was consistent across the four study months, or whether use by aquatic birds was specific to particular times of the breeding season, I compared species richness among months using a Friedman's test (non-parametric equivalent of repeated-measures ANOVA); pair-wise comparisons were made with Wilcoxon signed-rank tests. I tested for the presence of species richness – area relationships in all months by simple linear regression. I conducted a one-way ANCOVA with area as a covariate to test for differences in species richness among land-cover groups in May, the month with the strongest richness-area relationship.

Species occurrence on borrow-pits

I wanted to determine whether the same ponds were being used by aquatic birds across the four survey months, as well as if the frequency of occurrence of aquatic birds differed within months, among the three land-cover types. To test for differences in pond occupancy (by one or more species of aquatic birds) among the four months within the 2007 field season, I conducted a Cochran's q test (with McNemar tests for pair-wise comparisons). To test for differences in pond occupancy within months, among the three land-cover groups, I performed Kruskal-Wallis tests.

Indirect gradient analyses

I performed indirect gradient analysis on aquatic bird assemblage data in order to 1) visualize relationships among ponds and environmental variables using categorical overlays of land-cover and species richness. I also wanted to 2) determine what habitat features are associated with the occurrence of different species, in different months, and 3) if certain species of aquatic birds are characteristic of individual land-cover types. Indirect gradient analysis has advantages over direct gradient analyses, as it "lets the data tell its own story" (Clarke 1993), and does not constrain data to measured environmental variables (McCune and Grace 2002). Community data can then be related to environmental variables post hoc through correlations (McCune and Grace 2002).

Relationships among ponds and environmental variables

I used Principal Components Analysis (PCA) as an exploratory technique to examine the relationships among the study ponds and measured environmental variables, before relating patterns to bird assemblages, to see if ponds formed natural groupings. PCA is an indirect gradient analysis technique that works by reducing the dimensionality of a data set by transforming many, often correlated, variables into a smaller number of uncorrelated variables, or axes (Gotelli and Ellison 2004). It is an appropriate method for variables with approximately linear relationships and short gradient lengths, and frequently used for environmental data (McCune and Grace 2002). I conducted two PCAs, which are described below. Environmental variables used in ordinations included northing, SAV, proportions of emergent vegetation, riparian vegetation, pond area covered by emergent vegetation, forest and water within 500 m of a pond, distance to the nearest water body, area, distance to the road, and the presence of beaver and human activity. Proportions were arcsine square-root transformed prior to analyses.

I conducted a PCA on all environmental variables with the exception of proportion forest, grouped by land-cover type in the ordination bi-plot. I conducted a PCA with a correlation cross-products matrix which centers and standardizes all variables for better comparison with one another within the ordination. I conducted a Multi-response Permutation Procedure (MRPP) with Euclidean (Pythagorean) distance measure on the raw data matrix to determine if there were statistical multivariate differences in environmental characteristics among the three land-cover categories. This is a non-parametric test that tests for multivariate differences in the measured environmental variables between two or more pre-existing groups (McCune and Grace 2002). It is recommended to use the same distance measure in an MRPP as used in the initial ordination analysis (McCune and Grace 2002) therefore different distance measures were used in the MRPP tests following ordinations.

I used PCA with a correlation cross-products matrix to examine the relationship among all environmental variables (variables included in the previously described PCA in addition to the proportion forest within 500 m of a pond), with overlays of species richness categories for May and June to determine how species richness was related to environmental variables. Categories used were ponds with no birds (n = 20 ponds in May, n = 44 in June), ponds with one species (n = 48 ponds in May, n = 71 ponds in June), and ponds with two or more species (n = 132 ponds in May, n = 85 in June). I conducted MRPPs with Euclidean (Pythagorean) distance measure on the raw data matrix to determine if there were environmental differences among the ponds grouped by the three species richness categories in these two months.

Habitat features associated with occurrence of aquatic birds in different months

To determine what habitat variables are related to aquatic bird assemblages present on borrow-pits both in the spring (May) and summer (late June) I used Non-metric Multidimensional Scaling (NMS) to ordinate aquatic bird assemblage data for both May and June presence/absence species matrices. Based on preliminary Detrended Correspondence Analysis, gradient length was determined to be > 2 SD, indicating that linear methods such as PCA were inappropriate for bird assemblage data (ter Braak 1995). NMS is a distance-based ordination technique recommended as the most appropriate to use for community data (Clarke 1993) as it does not require linear relationships, nor is it negatively affected by data with many zeroes, or suffer from the "arch effect" exhibited by techniques such as Correspondence Analysis (McCune and Grace 2002). I included all species that were present on ≥ 5% of ponds; therefore there were some differences among species included in May (12 species) versus June (10 species) analyses. It was necessary to include a dummy variable 'ALL' constant (value of 1 for all ponds) in order to include all ponds in the ordination (including ponds with no birds), and to be able to properly compare May and June ordinations. I used 'slow and thorough' autopilot mode in PC-ORD 5.0 with Sorensen (Bray-Curtis) distance measure, recommended for community data (McCune and Grace 2002) and a random starting configuration. An MRPP was conducted on both May and June presence/absence raw data matrices, using Sorensen (Bray-Curtis) distance measure to test for differences in bird assemblages among the three land-cover groups. Environmental variables were correlated to scores on the NMS axes; variables having the strongest correlations were displayed as a joint plot with species data in order to assess habitat features behind ordinations of aquatic bird assemblages. It was necessary to use a joint-plot cutoff r^2 value of 0.10, as correlations of environmental variables with ordination axes were weak. In addition to the previously discussed environmental variables, I included species richness as an additional variable in the NMS joint plots, using species richness from the corresponding month, to visualize how individual species present on ponds are related to richness.

Assemblages characteristic of land-cover types

Because MRPP tests were significant, indicating assemblage differences among land-cover types, I performed indicator species analyses (see Dufrene and Legendre 1997) separately on May and June data grouped by land-cover category. Indicator species analysis allows identification of species characterizing specific site types (indicators). A "perfect" indicator species is always (and only) found on a particular site type (Dufrene and Legendre 1997, McCune and Grace 2002).

To further distinguish differences between ponds occupied and unoccupied by individual indicator species at a local scale, I conducted MRPP tests using Sorensen (Bray-Curtis) distance measure on the raw vegetation data matrix (including SAV, proportion emergent and riparian vegetation and proportion of pond covered by emergent vegetation), for each aquatic bird species that was identified as a land-cover type indicator for June. I chose to examine vegetation patterns in greater detail to determine if there were local (and thus non-land-cover) pond features, important for aquatic birds for both food and shelter, which may be related to the occurrence of indicator species. June occurrence data were used because these were closest in time to when vegetation data were recorded (August). I also conducted Mann-Whitney U tests to determine which vegetation variables differed between ponds where these indicator species were present or absent.

Results

Pond size and species richness comparisons

Pond area differed among land-cover groups, (ANOVA: $F_{2,197} = 9.14$, $p < 0.001$). Agricultural ponds ($\bar{x}$ ± SE = 0.53 ± 0.03 ha) were significantly smaller than either mixed (0.71 ± 0.08 ha, $p = 0.035$) or forested ponds (0.75 ± 0.04 ha, $p < 0.001$). Area did not differ between mixed and forested ponds ($p = 0.520$).

Species richness on constructed wetlands varied among survey months (Friedman test, $\chi^2_3 = 78.279$, $p < 0.001$). May richness (range: 0-9) was highest of all months and August richness (range: 0-7) was higher than July (range: 0-5; Wilcoxon signed-rank tests with Bonferroni $\alpha = 0.008$, $p \leq 0.002$; Figure 4.1). June richness ranged between 0-6.

Significant species-area relationships existed for all survey months (Figure 4.2). As the richness-area relationship was strongest in May ($r^2 = 0.18$), I conducted a one-way ANCOVA with area as a covariate to determine whether there were differences in species richness among the three land-cover groups after controlling for pond area. The interaction between log area and land-cover group was not significant ($F_{2,194} = 2.27$, $p = 0.106$) indicating that there was no difference in the slopes of the three regression lines. There was a significant effect of land-cover on May species richness after controlling for pond area ($F_{2,196} = 4.78$, $p = 0.009$). Pair-wise comparisons (using the Bonferroni adjustment) of species richness showed that ponds surrounded by mixed land-cover supported more species than ponds with either agricultural ($p = 0.029$) or forested ($p = 0.013$) land-covers. Richness did not differ between ponds with agricultural and forested land-covers ($p = 1.00$).

Occurrence of aquatic birds on borrow-pits

A pond was considered occupied if one or more individual of any species was present. Pond occupancy differed among survey months; May occupancy was highest (90%; McNemar tests with Bonferroni corrected $\alpha = 0.008$: $p \leq 0.001$) and there was no difference among other months (78 – 80%, $p \geq 0.66$; Table 4.1). There was no difference in pond occupancy among the three land-cover types in any of the four surveys (Kruskal-Wallis tests, May: $\chi^2_2 = 1.928$, $p = 0.381$; June: $\chi^2_2 = 2.999$, $p = 0.223$; July: $\chi^2_2 = 1.089$, $p = 0.580$, August: $\chi^2_2 = 0.008$, $p = 0.996$; Table 4.1). Appendix 4.1 lists the number of occupied ponds within each land-cover type during each survey.

Table 4.2 lists aquatic bird species using wetlands, classifying them as common (observed on each survey), occasional (observed on two or three surveys), or rarely observed (observed during only one survey), as well as whether breeding occurred (chicks observed), and a summary of species abundances throughout the summer (mean number of individuals of each species per pond). Twenty-seven species were observed; 13 were common, 10 were occasional, and four were rare. Thirteen species bred on borrow-pits over the course of the summer. The most commonly observed aquatic birds on constructed wetlands were Horned Grebe, Bufflehead, Ring-necked Duck and Lesser Scaup. Appendix 4.2 lists species' abundances for each of the three land-cover types in May, June, July and August.

Relationships among ponds and environmental variables

Table 4.3 summarizes means and ranges of all environmental variables used in ordination analyses. Figure 4.3 depicts results of PCA of ponds based on environmental data, grouped by land-cover category. PCA axes 1 and 2 were significant ($p = 0.001$) according to a randomization test, axes 1 and 2 explaining 24.83% and 14.67% of variance, respectively (totaling 39.50%), and thus a two dimensional solution was graphed and interpreted (Figure 4.3). An MRPP based on environmental variables for agricultural, mixed, and forested ponds revealed statistical significance ($A = 0.12$, $p < 0.001$). Pair-wise comparisons (with Bonferroni adjusted $\alpha = 0.017$) revealed statistically significant differences between each of the three land-cover types ($p < 0.001$ for agricultural versus mixed and agricultural versus forested, $p = 0.012$ for mixed versus forested). Although there was some overlap, most agricultural ponds were farther south and smaller, had less emergent, riparian, and submersed aquatic vegetation, and were less likely to have beaver activity than heavily forested ponds. There was also less water on the landscape surrounding ponds in agriculture-dominated areas. Mixed ponds were intermediate in their features between agricultural and forested ponds.

Figure 4.4 depicts PCA results of ponds based on environmental data, including proportion forest (omitted from the ordination in Fig. 4.3), grouped by species richness categories in May. The first two PCA axes were significant ($p = 0.001$), axes 1 and 2 explained 27.33% and 13.48% of variance, respectively (totaling 40.81%). The MRPP indicated statistically significant multivariate differences among the categories of species richness in May ($A = 0.03$, $p < 0.001$). Pair-wise comparisons (with Bonferroni adjusted $\alpha = 0.017$) indicated that ponds with 1 species differed from ponds with ≥ 2 species ($p < 0.001$), however, neither of these groups differed from ponds with no birds ($p \geq 0.21$). There was no difference among the categories of species richness in June (A = 0.002, $p = 0.26$). It appears that in May, ponds with one species were primarily found in the southern, agricultural areas, whereas ponds with two or more species tended to have more forest, increased beaver activity, and pond vegetation. Unoccupied ponds were distributed throughout landscape types, having varied environmental features.

Habitat features associated with occurrence of aquatic birds in different months

Non-metric multidimensional scaling for May presence/absence data for 12 aquatic bird species (reflecting pond use in the spring) revealed a four-axis solution, (indicating the number of dimensions, or axes that minimized the final stress of the ordination solution), with the first three axes explaining 60.4% of the variance (Table 4.4). Axes 1 and 2 were plotted for the ordination diagram, as they represent the most variation (44.2%) in bird assemblage data (Figure 4.5a). An MRPP based on land-cover (agriculture, mixed, forest) indicated significant differences (A = 0.07, $p < 0.001$) existed in bird assemblages among ponds associated with the three cover types. Pair-wise comparisons revealed that bird assemblages on agricultural ponds were different from those on mixed ponds and forested ponds ($p < 0.001$). Although significant at the $\alpha = 0.05$ level, bird assemblages on ponds with a mixed land-cover were not different from assemblages on forested ponds at the Bonferroni-adjusted $\alpha = 0.017$ level ($p = 0.026$).

Correlations of the NMS axes with the environmental data matrix and species richness are depicted in Table 4.4. The most highly correlated environmental variables are area, (10.4% of variance, axis 2), and UTM Northing, (9.1% of variance, axis 2; Table 4; Figure 4.5a). May species richness explained 56.1% of the variance in axis 2. May assemblages on larger, northern ponds were characterized by the presence of Mallard, Northern Shoveler, Bufflehead and American Wigeon, and had greater species richness. Assemblages characterized by Lesser Scaup and Horned Grebe were found on somewhat smaller southern ponds with lower species richness.

NMS based on June presence/absence of 10 aquatic bird species (reflecting pond use in early summer) yielded a three-axis solution, the three axes explaining 90.6% of the variance in bird community structure. Axes 1 and 2 were plotted in the final ordination, explaining 65.3% of the total variation (Figure 4.5b). An MRPP revealed significant differences ($A = 0.07$, $p < 0.001$) in assemblage structure among ponds located in the three land-cover types. Pair-wise comparisons revealed significant differences between ponds in agricultural and mixed land-covers ($p < 0.001$) as well as between agricultural and forested ponds ($p < 0.001$), but not between ponds in mixed and forested land-covers ($p = 0.11$). The most highly correlated environmental variable was the proportion of forest surrounding ponds, explaining 18.5% of the variance in axis 2 (Table 4.4; Figure 4.5b). June species richness was also highly correlated with NMS axes, explaining 37.7% of variance in axis 1 and 21.3% of variance in axis 2. Green-winged Teal, Bufflehead, Ring-necked Duck and American Wigeon characterized assemblages on ponds with the greatest amount of forest cover. Horned Grebe, American Coot, Mallard and Northern Shoveler characterized ponds surrounded by less forest and more agriculture. In June, species that characterized ponds with higher richness were American Wigeon, Lesser Scaup and Green-winged Teal, while Horned Grebe characterized ponds with lower species richness.

Assemblages characteristic of land-cover types

Results of indicator species analysis, based on Monte Carlo significance tests, for May and June presence/absence data are presented in Table 4.5.

For May assemblage data, I conducted this analysis two ways. I first grouped data based on the three land-cover types (agriculture, mixed and forest). Analyzed in this way, American Coot and Lesser Scaup were indicators of agricultural ponds and American Wigeon, Canvasback and Northern Shoveler were indicators of ponds with a 'mixed' land-cover. Bufflehead, Green-winged Teal and Ring-necked Duck were all indicators of heavily forested ponds. I also conducted indicator species analysis grouping ponds together if they were surrounded by more than 33.3% forest (as the 'mixed' and 'forest' groups did not differ based on MRPP tests), resulting in two groups: an 'agriculture' group and a 'mixed + forest' group. When the mixed and forested categories were collapsed into two land-cover types, Horned Grebe was also an indicator of agricultural ponds in May (in addition to American Coot and Lesser Scaup). American Wigeon, Bufflehead, Green-winged Teal and Ring-necked Duck were indicators of mixed + forested ponds in May; however, Canvasback and Northern Shoveler were no longer indicator species.

For June, I conducted indicator species analysis based on the ‘agriculture’ and ‘mixed + forest’ groups used for May, as mixed and forested ponds did not differ based on MRPP on June species composition. In June, Horned Grebe, Lesser Scaup and Mallard were indicators of agricultural ponds, and Bufflehead, Green-winged Teal and Ring-necked Duck were indicators of mixed + forest ponds (Table 4.5).

I conducted MRPP tests of vegetation data grouped by presence/absence of individual indicator species from June to determine the importance of local factors for breeding birds on ponds. Only patterns of occurrence for Bufflehead displayed a significant multivariate difference in vegetation between occupied and unoccupied ponds (Table 4.6). Ponds with Bufflehead had a significantly greater proportion of their perimeter covered by emergent vegetation as well as a greater area of the pond covered by emergent vegetation (Mann-Whitney U test: $n = 200$ ponds, $p = 0.014$ for both). However, when considering only the 109 ponds surrounded by greater than 33.3% forest (of which Bufflehead were indicators in June), there were no differences between ponds with and without Bufflehead for any of the vegetation metrics ($n = 109$ ponds, $p > 0.48$).

Discussion

My goal was to assess patterns of occurrence of aquatic birds on borrow-pits in the Peace Parkland. Wetlands in Alberta are very important to nesting aquatic birds in North America (Beyersbergen et al. 2004). Although Alberta has exhibited a loss of many natural wetlands (Bethke and Nudds 1995), there are hundreds of borrow-pits throughout the province that could potentially be used as habitat by different species of aquatic birds. I wanted to assess what species used borrow-pits, and if there were environmental features that explained species occurrence. Because land-cover differed greatly among ponds (and appeared to be important based on preliminary analyses), land-cover determined the major groupings of ponds used in this study. I was also interested if there was a difference in pond use (based on the measured environmental features at local and landscape scales) between spring (May) and early summer (June), reflecting differential use of borrow-pits during migration versus the breeding season and to reveal differences among species as well as habitat features of importance.

Characterization of borrow-pits as habitat

Habitat offered by agricultural, mixed and forested pond types was distinct according to PCA. Agricultural ponds were primarily in the southern end of the Peace Parkland, with less emergent and riparian vegetation and SAV, had a lower frequency of beaver activity, and less water on the surrounding landscape. Forested ponds were at the other end of this spectrum, farther north, with more emergent vegetation, riparian vegetation, more SAV, an increased frequency of beaver activity, and more water on the surrounding landscape. Mixed ponds were intermediate between these two pond types, but appeared to be more similar to forested ponds than to agricultural ponds in terms of their environmental features. Although all ponds were small, species richness was correlated with pond area in all months. However, this was a result of the landscape setting of ponds; agricultural ponds were smallest, and mixed and forested ponds were on average 0.2 ha larger than agricultural ponds. After controlling for area, ponds surrounded by a mixture of agriculture and forest attracted the most species in May. This indicates that pond area is not important in determining richness on borrow-pits.

Ponds with two or more species tended to have more forest surrounding them than ponds with one species (Fig. 4.4). Although agricultural ponds may be warmer and thus more productive early in the open water season (forested ponds may thaw more slowly due to shading), they may also be more exposed to inclement weather in May. Ponds with a mixed land-cover may offer some protection from the elements and may be more similar to natural parkland wetlands that provide habitat for many species in this study. Ponds with no birds were not different from either of these groups, indicating that empty ponds in May varied in their environmental features; there was no evidence from my study that empty ponds were in any way 'poor habitat' for aquatic birds, they were just unoccupied at the time of the survey.

Species characteristic of ponds within the three land-cover types

Although assemblages on mixed ponds were not statistically distinct from forested ponds, because the Bonferroni adjustment is highly conservative (Gotelli and Ellison 2004), I conducted indicator species analysis grouped by the three land-cover types and by agricultural and 'mixed + forested' ponds to assess whether the mixed pond type provided important habitat for any aquatic birds. American Wigeon, Canvasback and Northern Shoveler were identified as indicators of mixed land-cover type ponds in May, and only American Wigeon remained an indicator (of ponds with > 33.3% forest) when the mixed and forested groups were collapsed. This suggests that the mixed habitat type might be important for Canvasback (a diver) and Northern Shoveler (a dabbler) in the spring. By mid-May both of these species are in the middle of their peak migration period (Dubowy 1996, Mowbray 2002). Canvasback occurred on <5% of ponds by the June survey, and were therefore excluded from further analyses, and frequency of occurrence of Northern Shoveler had declined from 13% in May to 5% in June (Appendix 4.1). By June, bird assemblages did not differ between mixed and forested land-cover types; nor did environmental features differ among categories of species richness.

Ordinations and indicator species analysis in both May and June identified an assemblage of birds characteristic of forested ponds that included Bufflehead, Ring-necked Duck and Green-winged Teal. An assemblage characteristic of agricultural ponds included Lesser Scaup and American Coot (in May), and Horned Grebe and Mallard (in June). Horned Grebe was an indicator of agricultural ponds in May when mixed and forested land-cover types were combined, and was an indicator of agricultural ponds in June. Dwyer (1970) surveyed agricultural and partially (~60%) forested (protected park) potholes in the aspen parkland of southern Manitoba and noted greater use of agricultural potholes by divers such as Lesser Scaup, American Coot, Redhead, Canvasback, and Horned Grebe whereas dabblers, including Mallard and Blue-winged Teal, preferred forested potholes.

As noted earlier, forested ponds may be attractive to cavity nesting birds such as Bufflehead and goldeneye, however, in my study only Bufflehead was an indicator of forested ponds. Considering all 200 ponds, Bufflehead were present on ponds with a greater amount of emergent vegetation, both around and within the pond. However, amongst the 109 'mixed + forested' ponds for which Bufflehead were indicators in June, vegetation did not differ, suggesting that the landscape surrounding ponds with Bufflehead was more important in explaining occurrence. Common Goldeneye were more abundant in May than in other months (on 18/200 ponds in May), and broods appeared on some ponds in July and August (E. Kuczynski, unpublished data), however, their overall low abundance suggests that the species rarely used study ponds for nesting or brood-rearing. Common Goldeneye are abundant in other parts of Alberta, for example, they are one of the more abundant ducks breeding on wetlands in the Buffalo Lake Moraine (Corrigan 2007). Poysa and Virtanen (1994) found that brood-rearing lakes for Common Goldeneye were smaller than nesting lakes ($\bar{x}$ = 5.6 ha versus $\bar{x}$ = 20.2 ha). However, these Finnish lakes are almost ten times larger than my borrow-pits ($\bar{x}$ = 0.64 ha); thus borrow-pits may be too small to support Common Goldeneye broods.

Land-cover, or pond features that occurred within different land-covers, appears to be the dominant factor determining species assemblages on borrow-pits. Breeding birds may be sensitive to the amount of forest on the landscape and open, exposed ponds bordered by few trees may be attractive or not, leading to patterns of occurrence associated with land-cover types. Forest surrounding ponds may be unfavourable for some divers, like the Horned Grebe, that require a running take off from the waters' surface. Trees up to the edge of a pond might require birds to circle several times before taking flight, as observed by Dwyer

(1970) on small forested potholes in Manitoba. Mensing et al. (1998) found that at the 500 m scale, passerine diversity decreased with increasing proportion of cultivated agricultural land in Minnesota streamside riparian wetlands. Of the aquatic birds in their study, Blue-winged and Green-winged Teal were unique to agricultural sites (< 45% forest within 500 m) and Mallard preferred, but were not restricted to, agricultural sites (no aquatic birds were indicators of forested sites; Mensing et al. 1998). In contrast, Riffell et al. (2006) found that wetland associated birds, (passerines, and aquatic birds such as Wood Duck (*Aix sponsa*) and Great Blue Heron (*Ardea herodias*)) in southern Michigan were better predicted by forest characteristics, such as structure and heterogeneity, than wetland characteristics; forest area was also a greater predictor of species richness than wetland area.

Some results of my study contrast with findings from studies in other regions. Although Lesser Scaup on wetlands near Yellowknife, NWT appeared to avoid borrow-pits for brood rearing (Fast et al. 2004), they were one of the more abundant breeding species on ponds in my study. Borrow-pits in the Peace Parkland tend to be larger and deeper (mean size: 0.64 ha, mean depth 2.75 m, depth based on subset of 29 ponds) than borrow-pits in the Yellowknife study area (median size < 0.1 ha, depth: unmeasured but reported as "semi-permanent"; Fournier and Hines 1999) which could account for relatively low use by divers in NWT. In addition, I found scaup to be indicators of agricultural ponds in both May and June; whereas Austin et al. (1998) stated that the boreal forest and parkland contain the primary nesting habitat for scaup. Agricultural areas in the

Peace Parkland are likely similar to natural parkland, but I found scaup to be relatively uncommon on forested ponds.

Habitat overlap among species

There appears to be habitat overlap among some birds, suggesting potential competition for resources at the small sites studied here. Two such species that have similar NMS scores for axes 1 and 2, and are often found together on ponds in agricultural areas, are Horned Grebe and American Coot, present together on 12 ponds (9 agricultural) in May and 8 in June (5 agricultural). Horned Grebes were present on 80% of ponds that contained coots in both months. Nudds (1982) argued that although there is macrohabitat overlap between these two species, they differentiate along a microhabitat scale of vegetation – water interspersion, using different parts of a wetland; grebes use open water areas and coots use more vegetated areas. There is thus little evidence for interference competition, resulting from direct negative interactions (Nudds 1982). Grebes and coots continued to separate at a microhabitat scale in both low and high water years (Barnes and Nudds 1990). Use of different microhabitats likely extends to other cohabitating aquatic birds as well, such as Bufflehead and Ring-necked Duck, present together on 21 ponds in May and 14 in June.

Ability of environmental variables to explain species composition

Based on correlation with NMS axes, the measured environmental variables had little ability to predict the composition of bird assemblages, in either month, as even the strongest correlations had relatively small r^2 values. However, correlations between ordination axes and environmental variables were higher for

May than June (Table 4.4). In particular, pond area and UTM northing explained larger portions of assemblage variation in May. These patterns could be a consequence of the northward movement of birds, and overall differential use of ponds, during migration. Area and northing are confounded with proportion of forest on the landscape, as agricultural ponds are smaller and primarily in the south, and forested ponds are larger and primarily in the north.

The amount of, and distance to, water on the landscape explained very little variation in bird assemblages, although the amount of water on the landscape was correlated to some degree with species richness (Fig. 4.4). Because borrow-pits are constructed, very few are directly connected to natural sources of water on the landscape. Wetland connectivity and the amount of water on the landscape can be very important for aquatic birds (Brown and Dinsmore 1986, Fairbairn and Dinsmore 2001). In fact, Whited et al. (2000) found that wetland connectivity was the best predictor of bird species richness in both agricultural and forested landscapes in Minnesota, USA, and Guadagnin and Maltchik (2007) found that wetland connectivity can increase aquatic bird species richness in Brazil even on small sites.

Seasonal patterns

Both occurrence and species richness were highest in May, most likely indicative of birds using ponds temporarily as they migrated further north. A similar influx of migrants was likely observed in August, as species richness was higher than in July. In early August, birds were beginning their southward migration, and birds of the year were leaving breeding ponds. When looking in detail at May versus June patterns of pond use, it appears that aquatic birds might be less selective in May than in June. By June, birds had either departed for other areas or settled to breed, and then had narrower patterns of habitat use. This is suggested by the greater proportion of the variance in the bird assemblage composition explained by the ordination in June (90.6%) than in May (60.4%). However, less variation in bird assemblages was explained by specific environmental variables in June. This result suggests that although use may be more structured in June, I was not successful at identifying and measuring the important pond features that determined use. In May, unlike June, indicator species existed for all three land-cover types, perhaps reflecting consistent pond use by some species during migration and settling linked to landscape characteristics. Patterns of indicator species varied seasonally and many birds (both individuals and entire species) departed all together. Species richness on eight roadside natural wetlands in the Peace Parkland also appeared to be higher in May (range: 1 – 8) than in June (range: 0 – 4), indicating that this pattern may extend to natural waterbodies in the region.

Benefits of wetland construction

Borrow-pits represent a source of stable wetland habitat. In the prairie pothole region, the number of wetlands fluctuates greatly year to year which influences breeding bird numbers (Niemuth and Solberg 2003). Austin (2002) found that dabbling ducks were very sensitive to yearly fluctuations in water levels, and some species, such as Blue-winged Teal, will fly to northern areas in low water years, bypassing regular prairie breeding areas (Rohwer et al. 2002).

Many wetlands in the prairie pothole region of Canada have already been lost (70% in some areas; Mitsch and Gosselink 2000). Northern wetlands are likely to become more important in years to come as wetlands in the prairie pothole region are predicted to become less productive for breeding aquatic birds with increasing climate warming and decreasing water levels (Johnson et al. 2005). Currently wetlands in northern Canada offer lower levels of primary productivity, but have more stable water levels as temperature and precipitation do not fluctuate as widely as they do in the southern prairies (Bethke and Nudds 1993, Johnson et al. 2005).

Conclusions

Constructed borrow-pit wetlands in northwestern Alberta are a source of permanent water and are used by a variety of dabbling and diving aquatic birds, both during migration and during the breeding season. These ponds deserve consideration as habitat in aquatic bird conservation planning. The Peace Parkland spans a transition area between southern prairie and northern boreal forest. Borrow-pits are widespread, following the length of the highways travelling through this heterogeneous landscape, and provide summer habitat for birds with a variety of breeding and foraging requirements. Similar to agricultural wetlands created functionally for rice and cranberry cultivation (Czech and Parsons 2002), borrow-pit ponds incidentally create habitat for a variety of species.

Literature Cited

Austin J. E. 2002. Responses of dabbling ducks to wetland conditions in the prairie pothole region. Waterbirds **25**:465-473.

Austin J. E., C. M. Custer, and A. D. Afton. 1998. Lesser Scaup (*Aythya affinis*), (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/338.

Barnes G. G., and T. D. Nudds. 1990. Temporal variation in microhabitat relationships among grebes and coots. The Wilson Bulletin **102**:99-108.

Bayley S. E., and C. M. Prather. 2003. Do wetland lakes exhibit alternative stable states? Submersed aquatic vegetation and chlorophyll in western boreal shallow lakes. Limnology and Oceanography **48**:2335-2345.

Bethke R. W., and T. D. Nudds. 1993. Variation in the diversity of ducks along a gradient of environmental variabllity. Oecologia **93**:242-250.

Bethke R. W., and T. D. Nudds. 1995. Effects of climate change and land use on duck abundance in Canadian prairie-parklands. Ecological Applications **5**:588-600.

Beyersbergen G. W., N. D. Niemuth, and M. R. Norton. 2004. Northern Prairie and Parkland Waterbird Conservation Plan. A plan associated with the Waterbird Conservation for the Americas initiative. Denver, Colorado: Prairie Pothole Joint Venture; 183pp.

Brown M., and J. J. Dinsmore. 1986. Implications of marsh size and isolation for marsh bird management. Journal of Wildlife Management **50**:392-397.

Clarke K. R. 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology **18**:117-143.

Corrigan R. 2007. Effectiveness of nest boxes in influencing population trends for Common Goldeneye (*Bucephala clangula*) and Bufflehead (*Bucephala albeola*) in the Buffalo Lake Moraine. M. Sc. Thesis. University of Alberta, Edmonton, Alberta, Canada.

Czech H. A., and K. C. Parsons. 2002. Agricultural wetlands and waterbirds: a review. Waterbirds **25**:56-65.

Dubowy P. J. 1996. Northern Shoveler (*Anas clypeata*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/217. DOI:10.2173/bna.217.

Dufrene M., and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs **67**:345-366.

Dwyer T. J. 1970. Waterfowl breeding habitat in agricultural and nonagricultural land in Manitoba. The Journal of Wildlife Management **34**:130-136.

Dzus E. H., and R. G. Clark. 1997. Overland travel, food abundance, and wetland use by Mallards: relationships with offspring survival. The Wilson Bulletin **109**:504-515.

Elmberg J., P. Nummi, H. Poysa, and K. Sjoberg. 1994. Relationships between species number, lake size and resource diversity in assemblages of breeding waterfowl. Journal of Biogeography **21**:75-84.

Fairbairn S. E., and J. J. Dinsmore. 2001. Local and landscape-level influences on wetland bird communities of the prairie pothole region of Iowa, USA. Wetlands **21**:41-47.

Fast P. L. F., R. G. Clark, R. W. Brook, and J. E. Hines. 2004. Patterns of wetland use by brood-rearing Lesser Scaup in northern boreal forest of Canada. Waterbirds **27**:177-182.

Fournier M. A., and J. E. Hines. 1999. Breeding ecology of the Horned Grebe (*Podiceps auritus*) in subarctic wetlands. Canadian Wildlife Service; Occasional paper 99.

Gotelli N. J., and A. M. Ellison. 2004. A primer of ecological statistics. Sinauer Associates, Inc. Publishers, Sunderland, Massachusetts, U.S.A.

Guadagnin D. L., and L. Maltchik. 2007. Habitat and landscape factors associated with neotropical waterbird occurrence and richness in wetland fragments. Biodiversity and Conservation **16**:1231-1244.

Johnson W. C., B. V. Millett, T. Gilmanov, R. A. Voldseth, G. R. Guntenspergen, and D. E. Naugle. 2005. Vulnerability of northern prairie wetlands to climate change. BioScience **55**:863-872.

McCune B., and J. B. Grace. 2002. Analysis of ecological communities. MjM Software Design, Oregon, USA.

McCune B., and M. J. Mefford. 1999. Multivariate analysis of ecological data. Version 5.0. MjM Software, Gleneden Beach, Oregon, USA.

McParland C. E., and C. A. Paszkowski. 2007. Waterbird assemblages in the Aspen Parkland of western Canada: the influence of fishes, invertebrates, and the environment on species composition. Ornithological Science **6**:53-65.

Mensing D. M., S. M. Galatowitsch, and J. R. Tester. 1998. Anthropogenic effects on the biodiversity of riparian wetlands of a northern temperate landscape. Journal of Environmental Management **53**:349-377.

Mitsch W. J., and J. G. Gosselink. 2000. Wetlands. John Wiley & Sons, New York.

Mowbray T. B. 2002. Canvasback (*Aythya valisineria*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/659. DOI:10.2173/bna.659.

Niemuth N. D., and J. S. Solberg. 2003. Response of waterbirds to number of wetlands in the prairie pothole region of North Dakota, U.S.A. Waterbirds **26**:233-238.

Nudds T. D. 1982. Ecological separation of grebes and coots: interference competition or microhabitat selection? The Wilson Bulletin **94**:505-514.

Paracuellos M., and J. Telleria. 2004. Factors affecting the distribution of a waterbird community: the role of habitat configuration and bird abundance. Waterbirds **27**:446-453.

Paszkowski C. A., and W. M. Tonn. 2000. Effects of lake size, environment, and fish assemblage on species richness of aquatic birds. Verh. Internat. Verein. Limnol. **27**:178-182.

Poysa H., and J. Virtanen. 1994. Habitat selection and survival of Common Goldeneye (*Bucephala clangula*) broods - preliminary results. Hydrobiologia **279/280**:289-296.

Riffell S., T. Burton, and M. Murphy. 2006. Birds in depressional forested wetlands: area and habitat requirements and model uncertainty. Wetlands **26**:107-118.

Rohwer F. C., W. P. Johnson, and E. R. Loos. 2002. Blue-winged Teal (*Anas discors*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/625. DOI:10.2173/bna.625.

ter Braak C. J. F. 1995. Ordination. Pages 91 - 173 *In* R. H. G. Jongman, C. J. F. ter Braak and O. F. R. van Tongeren, eds. Data analysis in community and landscape ecology. Cambridge University Press, Cambridge, UK.

Whited D., S. Galatowitsch, J. R. Tester, K. Schik, R. Lehtinen, and J. Husveth. 2000. The importance of local and regional factors in predicting effective conservation: Planning strategies for wetland bird communities in agricultural and urban landscapes. Landscape and Urban Planning **49**:49-65.

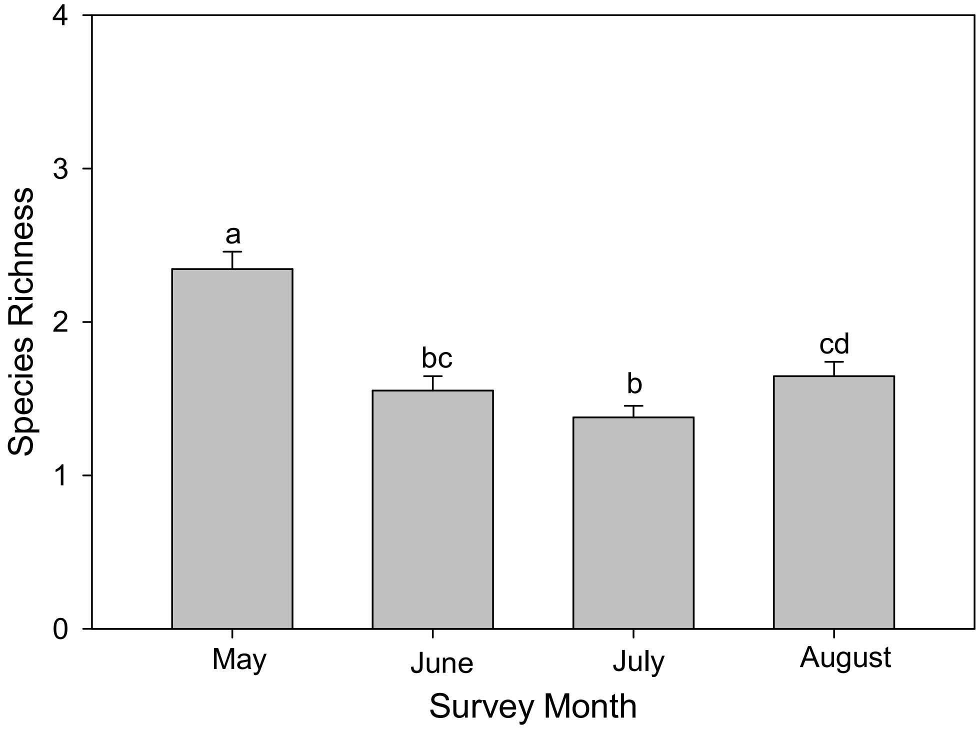


Figure 4.1: Mean species richness on 200 constructed ponds in the Peace Parkland, Alberta over four monthly surveys in 2007. Letters above bars indicate results according to Mann-Whitney U tests (see text).

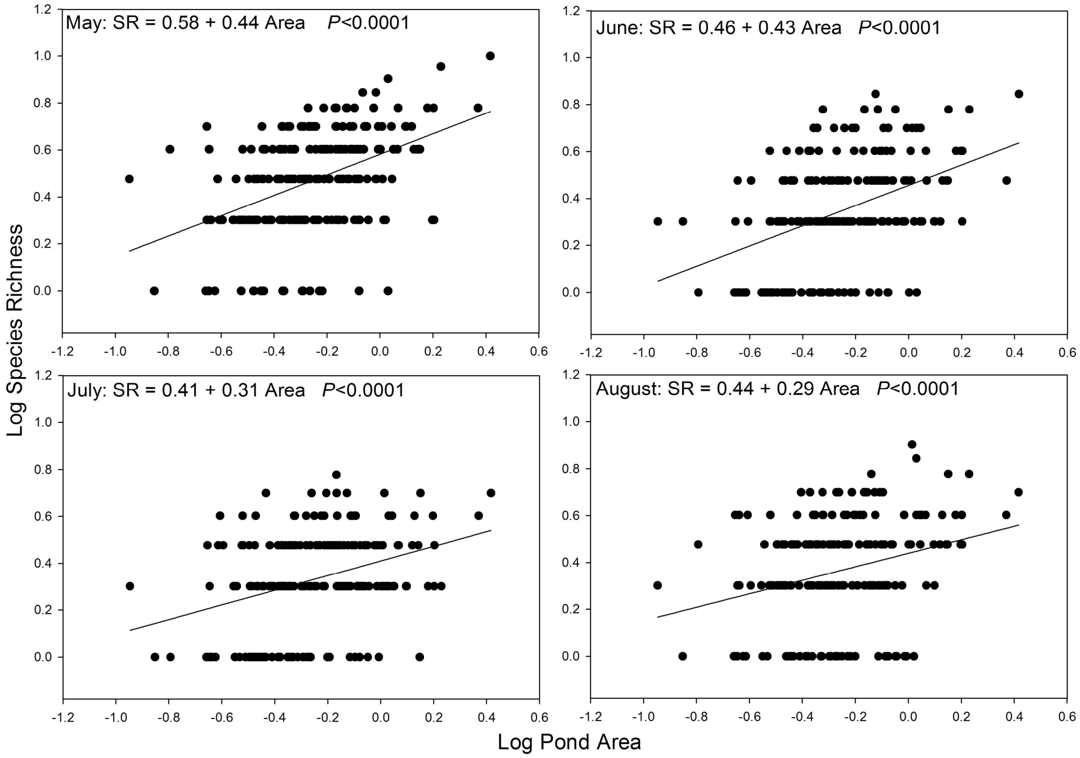


Figure 4.2: Regressions between log (bird species richness + 1); SR and log (pond area, ha) for 200 ponds in the Peace Parkland of Alberta in May, June, July and August 2007. 1 was added to the richness of all ponds, including those with zero birds. May: $F_{1,198} = 46.39$, $P<0.0001$, $R^2_{adj} = 0.19$; June: $F_{1,198} = 42.73$, $P<0.0001$, $R^2_{adj} = 0.17$; July: $F_{1,198} = 26.26$, $P<0.0001$, $R^2_{adj} = 0.11$; August: $F_{1,198} = 17.59$, $P<0.0001$, $R^2_{adj} = 0.08$.

Table 4.1: Percent occupancy by any species of aquatic bird in May, June, July and August 2007 on 200 ponds in agricultural (0-33.3% forest within a 500 m pond buffer, n = 91), mixed (33.4-66.6% forest, n = 44) and forested (66.7-100% forest, n = 65) landscapes in the Peace Parkland, Alberta.

Survey month	Agriculture	Mixed	Forest	Total
May	87.91	95.45	89.23	90.00
June	72.53	84.09	81.54	78.00
July	76.92	84.09	81.54	80.00
August	80.22	79.55	80.00	80.00

Table 4.2: Summary of aquatic birds observed on 200 constructed wetlands in northwestern Alberta in May – August 2007. Status codes are B = breeding (chicks observed), C = common (observed on all surveys), O = occasional (observed on more than one survey), R = rare (observed once). Mean species abundance, adults per pond, is presented for May, June, July, August.

				Species Abundance (adults)			
Common name	**Code**	**Latin name**	**Status**	**May**	**June**	**July**	**August**
American Coot	AMCO	*Fulica americana*	C,B	0.1	0.06	0.15	0.09
American Wigeon	AMWI	*Anas americana*	C,B	0.27	0.13	0.04	0.07
Barrow's Goldeneye	BAGO	*Bucephala islandica*	O	0.02	0.01	0	0
Black Tern	BLTE	*Chlidonias niger*	R	0	0	0	0.01
Blue-winged Teal	BWTE	*Anas discors*	O	0.14	0.08	0.02	0
Bufflehead	BUFF	*Bucephala albeola*	C,B	0.84	0.53	0.39	0.1
Canada Goose	CAGO	*Branta canadensis*	C,B	0.04	0.06	0.12	0.1
Canvasback	CANV	*Aythya valisineria*	C,B	0.27	0.04	0.11	0.23
Common Goldeneye	COGO	*Bucephala clangula*	C,B	0.17	0.05	0.07	0.02
Common Snipe	COSN	*Gallinago gallinago*	O	0.04	0.005	0	0.01
Common Tern	COTE	*Sterna hirundo*	R	0.01	0	0	0
Gadwall	GADW	*Anas strepera*	O	0	0.01	0.005	0.01
Green-winged Teal	GWTE	*Anas crecca*	O,B	0.17	0.07	0	0.03
Hooded Merganser	HOME	*Lophodytes cucullatus*	R	0	0	0	0.01
Horned Grebe	HOGR	*Podiceps auritus*	C,B	0.91	0.57	0.48	0.04
Lesser Scaup	LESC	*Aythya affinis*	C,B	0.55	0.63	0.13	0.23
Lesser Yellowlegs	LEYE	*Tringa flavipes*	O	0.005	0	0	0.01
Mallard	MALL	*Anas platyrhynchos*	C,B	0.41	0.11	0.04	0.2
Northern Pintail	NOPI	*Anas acuta*	O	0.02	0	0	0.01
Northern Shoveler	NSHO	*Anas clypeata*	C,B	0.32	0.09	0.02	0.02
Redhead	REDH	*Aythya americana*	C	0.04	0.04	0.005	0.005
Ring-necked Duck	RNDU	*Aythya collaris*	C,B	0.76	0.32	0.2	0.26
Ruddy Duck	RUDU	*Oxyura jamaicensis*	C,B	0.07	0.04	0.01	0.04
Solitary Sandpiper	SOSA	*Tringa solitaria*	O	0.005	0.005	0	0.02
Sora	SORA	*Porzana carolina*	O	0	0.01	0.005	0
Spotted Sandpiper	SPSA	*Actitis macularia*	O	0	0.01	0	0.04
Surf Scoter	SUSC	*Melanitta perspicillata*	R	0.02	0	0	0

Table 4.3: Summary of environmental variables used in analyses grouped by agriculture (0-33.3% forest within a 500 m pond buffer, n = 91), mixed (33.4-66.6% forest, n = 44) or forest (66.7-100% forest, n = 65).

		Agriculture n = 91		**Mixed n = 44**		**Forest n = 65**	
Environmental variable	**Abbreviation**	**Mean ± SE**	**Range**	**Mean ± SE**	**Range**	**Mean ± SE**	**Range**
Northing	UTM N	6286221 ± 13564.07	6146156 - 6486264	6381155 ± 18651.06	6142988 - 6506431	6425618 ± 10661.47	6142977 - 6517349
Submersed aquatic vegetation (SAV; rank 1 - 5)	SAV	3.13 ± 0.10	1 - 5	3.43 ± 0.14	2 - 5	3.6 ± 0.12	2 - 5
Proportion of perimeter covered in emergent vegetation	emergent	0.61 ± 0.04	0 - 1	0.83 ± 0.04	0 - 1	0.88 ± 0.03	0.03 - 1
Proportion of perimeter covered in riparian vegetation	riparian	0.59 ± 0.04	0 - 1	0.64 ± 0.78	0 - 1	0.81 ± 0.03	0 - 1
Proportion of pond surface covered by emergent vegetation	area emergent	0.17 ± 0.02	0 - 0.75	0.27 ± 0.03	0 - 0.8	0.31 ± 0.03	0 - 1
Proportion of water within 500 m buffer	water	0.01 ± 0.0005	0.002 - 0.03	0.01 ± 0.002	0 - 0.08	0.02 ± 0.004	0 - 0.22
Distance to nearest waterbody (m)	dist. from water	442.73 ± 27.83	32.06 - 1086.97	491.16 ± 107.24	32.59 - 4791.98	585.55 ± 104.10	89.82 - 5830.66
Pond area (ha)	area	0.53 ± 0.03	0.22 - 1.60	0.71 ± 0.08	0.11 - 2.61	0.75 ± 0.04	0.23 - 1.70
Distance from road to pond (m)	dist. from road	31.76 ± 1.76	10.06 - 126.19	38.88 ± 3.60	8.23 - 100.58	45.82 ± 2.71	20.12 - 118.87
Beaver activity (presence/absence)	beaver						
Human activity (presence/absence)	human						

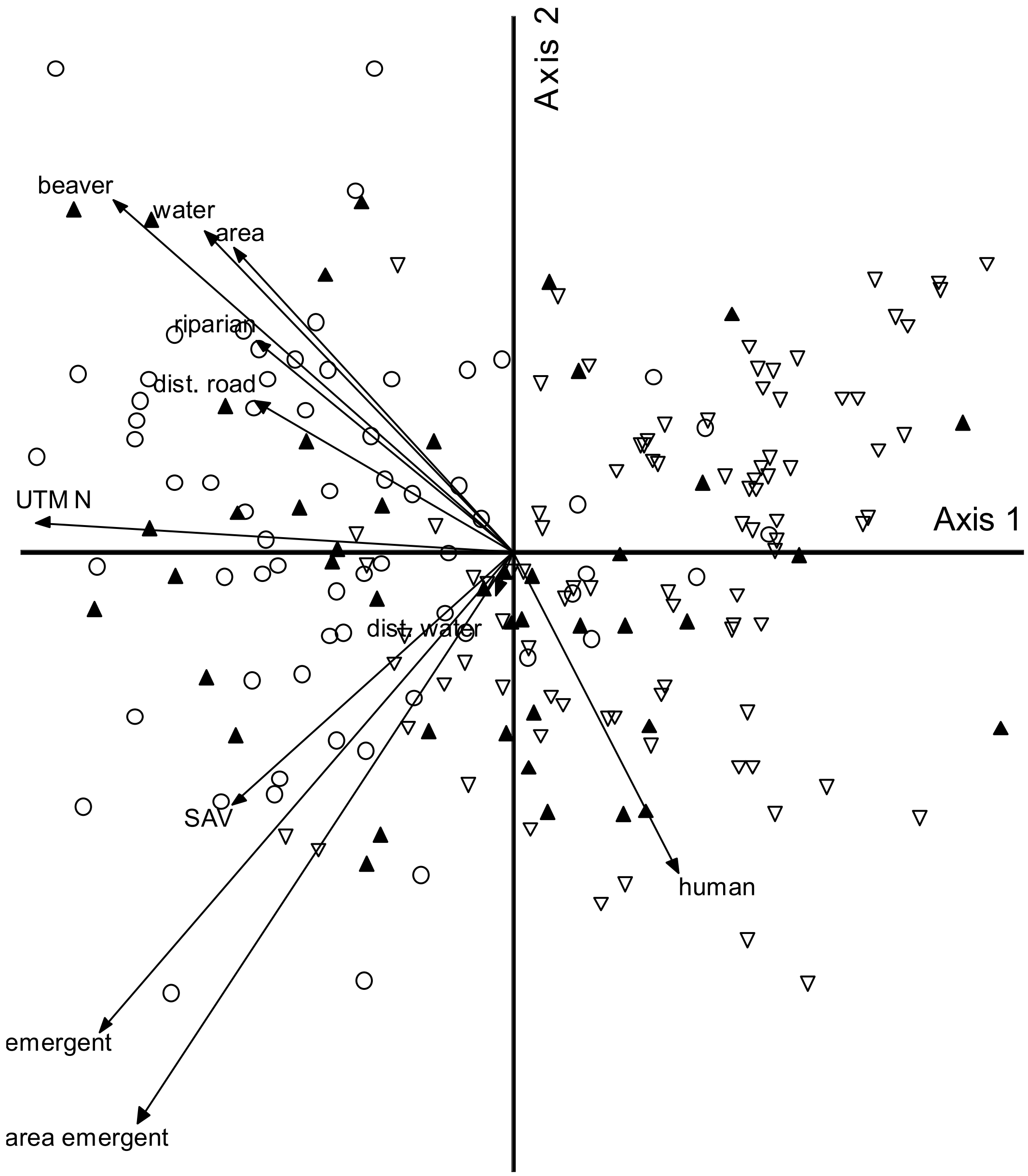


Figure 4.3: Principal Components Analysis bi-plot of 200 borrow-pit ponds based on environmental variables coded by agriculture (0-33.3% forest; open triangles, n = 91), mixed (33.4-66.6% forest; closed triangles, n = 44) or forest (66.7-100% forest; open circles, n = 65) land-cover types, as determined within a 500 m pond buffer area. Vectors indicate the strength and direction of environmental variables (see Table 4.3 for abbreviations and description of variables).

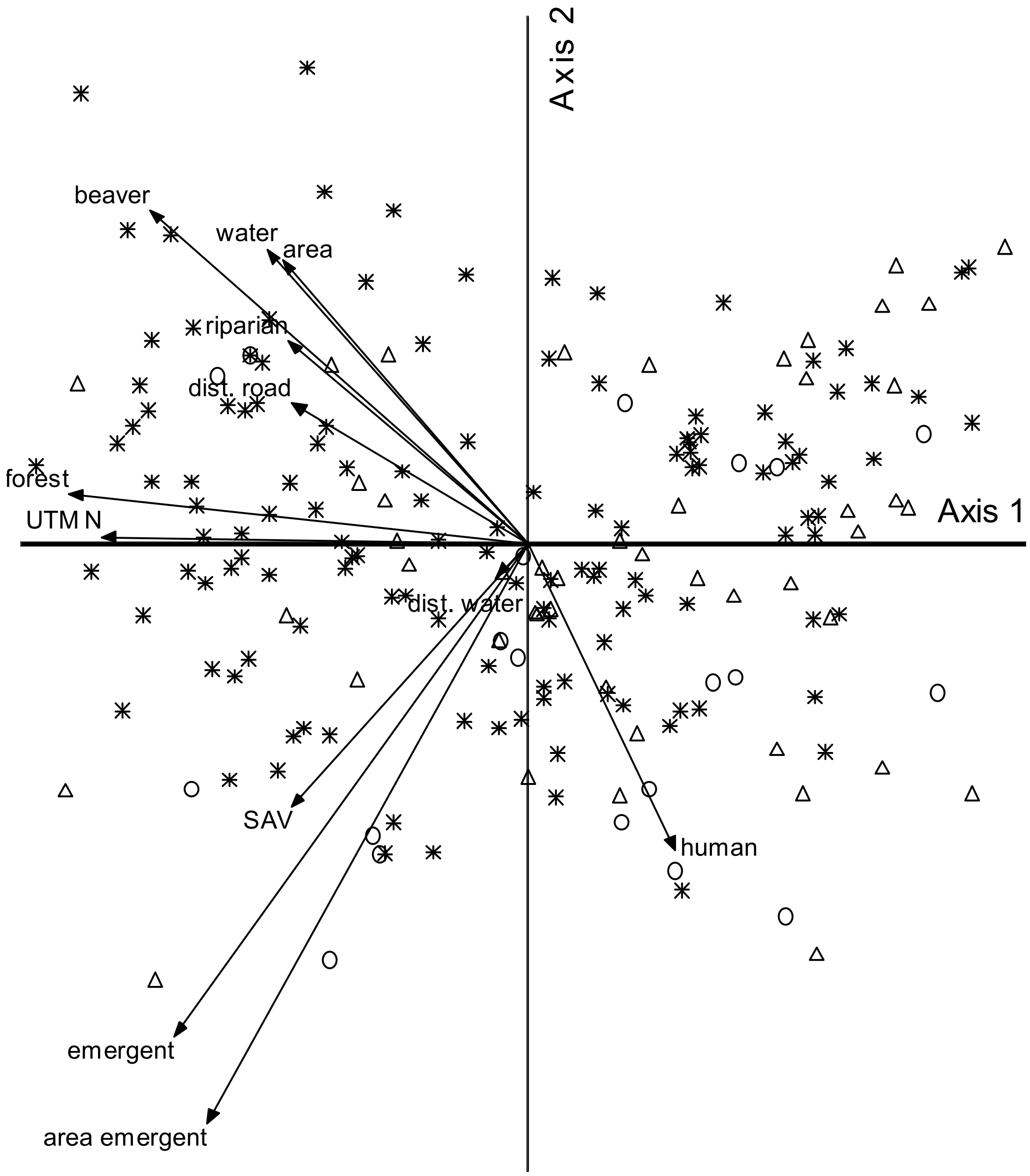


Figure 4.4: Principal Components Analysis bi-plot of 200 borrow-pit ponds based on environmental variables coded by categories of species richness in May. Open circles = ponds with 0 birds (n = 20), open triangles = ponds with 1 species (n = 48), stars = ponds with ≥ 2 species (n = 132). Vectors indicate the strength and direction of environmental variables (see Table 4.3 for abbreviations and description of variables; forest = proportion forest within 500 m).

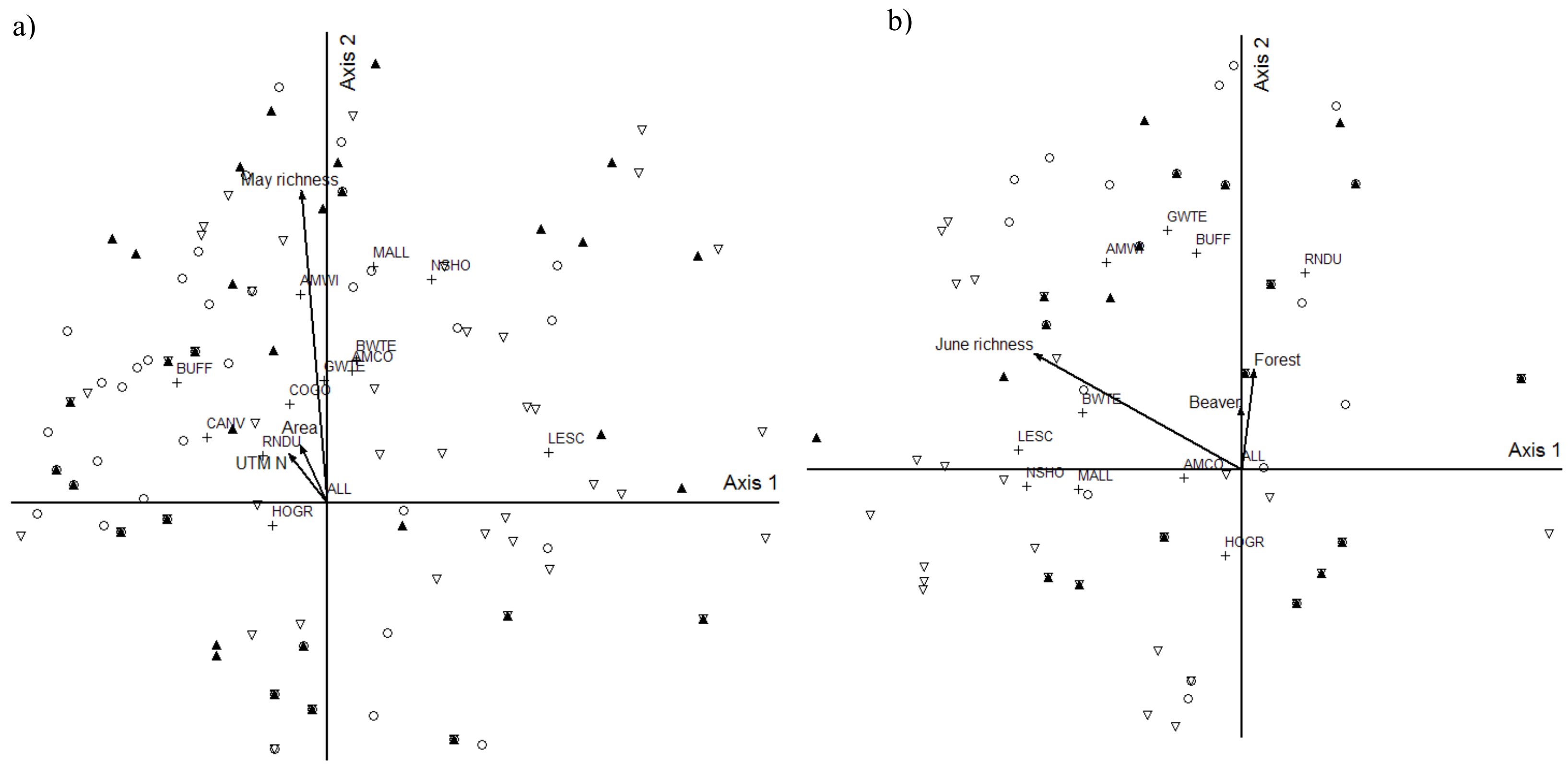


Figure 4.5: Non-metric multidimensional scaling joint-plots based on a) May presence/absence of 12 aquatic bird species and b) June presence/absence 10 aquatic bird species across 200 ponds surveyed in the Peace Parkland of Alberta. Vectors indicate environmental variables with $r^2 \geq 0.10$ correlations with ordination axes, vectors are scaled by 300% for greater visibility. ALL is a dummy variable (constant value of 1 for all ponds) in order to keep all ponds in analyses (see text). See Table 2 for species codes and Table 3 for environmental variable abbreviations. May richness and June richness is the species richness in that month. Open triangles: ponds with between 0-33.3% forest within a 500m pond buffer (agricultural ponds, n = 91), closed triangles: ponds with 33.4-66.6% forest (mixed, n = 44), open circles: ponds with 66.7-100% forest (forested ponds, n = 65).

Table 4.4: Variance (r^2) in aquatic bird assemblage composition explained by correlated environmental variables for three non-metric multidimensional scaling ordination axes based on survey data from 200 ponds in the Peace Parkland of Alberta. See Table 4.3 for units associated with environmental variables.

	Axis 1	**Axis 2**	**Axis 3**	**Cumulative**
May presence/absence				
Variance explained (r^2)	0.182	0.259	0.162	0.604
Proportion forest	0.098	0.016	0.137	
Proportion water	0.024	0.073	0.006	
Distance to nearest waterbody	0.005	0.008	0.001	
UTM – Northing	0.071	0.091	0.056	
Distance road to pond	0.005	0.005	0.047	
Area	0.05	0.104	0.055	
Beaver activity	0.044	0.075	0.074	
Human activity	0.013	0.023	0.019	
SAV	0.005	<0.001	0.035	
Proportion emergent vegetation	0.034	0.009	0.045	
Proportion riparian vegetation	0.035	0.002	0.048	
Proportion area covered by emergent vegetation	0.001	0.001	0.055	
May species richness	0.046	0.561	0.086	
June presence/absence				
Variance explained (r^2)	0.284	0.369	0.252	0.906
Proportion forest	0.022	0.185	0.01	
Proportion water	<0.001	0.064	0.001	
Distance to nearest waterbody	0.005	<0.001	<0.001	
UTM – Northing	<0.001	0.085	0.004	
Distance road to pond	0.018	0.006	0.004	
Area	0.043	0.074	0.063	
Beaver activity	0.002	0.117	0.009	
Human activity	0.02	0.02	0.004	
SAV	0.008	0.003	<0.001	
Proportion emergent vegetation	0.015	0.042	0.019	
Proportion riparian vegetation	<0.001	0.008	0.002	
Proportion area covered by emergent vegetation	0.029	0.011	<0.001	
June species richness	0.377	0.213	0.254	

Table 4.5: Monte Carlo test of significance results for indicator species analysis for May and June based on aquatic bird species presence/absence data grouped by land-cover type determined using a 500 m buffer surrounding ponds (see text). ‘Agriculture’ = 0-33.3% forest (91 ponds), ‘mixed’ = 33.4-66.6% forest (44 ponds), ‘forest’ = 66.7-100% forest (65 ponds), ‘mixed + forest’ = 33.4-100% forest (109 ponds). *P* values in bold indicate statistical significance. N/A indicates species that were present in <5% abundance in June and excluded from analyses. See Table 4.2 for species codes.

	May								June			
Species	**Land-cover**	**Observed indicator value**	**Random indicator value (±SD)**	***P* value**	**Land-cover**	**Observed indicator value**	**Random indicator value (±SD)**	***P* value**	**Land-cover**	**Observed indicator value**	**Random indicator value (±SD)**	***P* value**
AMCO	agriculture	9.20	4.50 (± 1.68)	**0.0186**	agriculture	10.50	4.9 (± 1.40)	**0.0038**	agriculture	4.20	4.00 (±1.20)	0.5161
HOGR	agriculture	24.20	20.60 (± 2.47)	0.088	agriculture	34.70	28.00 (± 2.33)	**0.0156**	agriculture	29.90	24.00 (±2.34)	**0.0224**
LESC	agriculture	13.70	8.70 (± 2.10)	**0.028**	agriculture	18.50	10.60 (± 1.93)	**0.0028**	agriculture	18.70	12.20 (±1.97)	**0.0118**
AMWI	mixed	14.50	8.00 (± 2.06)	**0.0156**	mixed + forest	14.10	9.8 (± 1.80)	**0.0446**	mixed + forest	8.20	6.40 (±1.58)	0.1338
BWTE	mixed	2.60	4.30 (± 1.67)	0.8646	agriculture	3.60	4.6 (± 1.28)	0.7716	mixed + forest	3.50	4.60 (±1.28)	1.0000
CANV	mixed	12.00	4.90 (± 1.70)	**0.0058**	mixed + forest	8.50	5.50 (± 1.43)	0.0558	N/A			
COGO	mixed	4.60	5.60 (± 1.81)	0.7435	mixed + forest	5.70	6.40 (± 1.54)	0.6257	N/A			
MALL	mixed	9.00	11.10 (± 2.26)	0.8196	agriculture	12.70	14.10 (± 2.10)	0.7317	agriculture	7.70	4.60 (±1.28)	**0.0380**
NSHO	mixed	17.30	7.10 (± 1.99)	**0.0008**	mixed + forest	7.70	8.40 (± 1.68)	0.6847	agriculture	4.20	4.00 (±1.19)	0.5163
BUFF	forest	24.30	18.20 (± 2.42)	**0.0188**	mixed + forest	40.20	24.50 (± 2.35)	**0.0002**	mixed + forest	41.20	18.00 (±2.22)	**0.0002**
GWTE	forest	11.40	6.70 (± 1.88)	**0.0182**	mixed + forest	19.10	7.8 (± 1.69)	**0.0002**	mixed + forest	6.40	3.70 (±1.21)	**0.0378**
RNDU	forest	16.40	9.80 (± 2.16)	**0.0122**	mixed + forest	21.70	12.20 (± 1.95)	**0.0010**	mixed + forest	15.60	7.80 (±1.64)	**0.0010**

Table 4.6: Results from multi-response permutation procedure tests of multivariate differences in vegetation metrics (proportion emergent vegetation, proportion riparian vegetation, proportion pond area covered by emergent vegetation and submersed aquatic vegetation) between 200 ponds in the Peace Parkland on which indicator species were present or absent in June. *P* value in bold indicates statistical significance. See Table 4.2 for species codes.

Species	**A**	***P* value**
HOGR	-0.002	0.761
LESC	0.004	0.126
MALL	-0.0003	0.436
BUFF	0.007	**0.041**
GWTE	0.002	0.211
RNDU	0.002	0.202

Chapter 5

General discussion

Summary of main findings

Borrow-pits in the Peace Parkland provide summer habitat for Horned Grebes, in addition to a variety of other surface feeding and diving aquatic birds. Ponds are used both as rest stops during migration and for breeding. Horned Grebe occupancy and chick production on borrow-pits in the Peace Parkland is high compared to other areas in Canada, regardless of wetland origin (constructed or natural). I also found evidence that grebes may return to the same ponds year after year, however, banding would be required to determine whether this is true. Aquatic birds in the Peace Parkland, Horned Grebes included, are attracted to ponds with a variety of habitat features which, in general, are correlated with the amount of forested or agricultural land-cover surrounding ponds. I identified indicator species of different land-cover types at different points in the spring (May) and summer (June). Species richness is highest on ponds with a mixture of forest and agriculture surrounding them in May, when birds are likely both moving among ponds locally and making long distance migrations to more northerly breeding areas. Horned Grebes are indicators of agricultural ponds, with emergent and riparian vegetation surrounding them. These agricultural ponds also support chicks; there is evidence that ponds with the greatest amount of surrounding riparian vegetation are most likely to produce chicks. Beaver activity, as well as the presence of within-pond human structures, appears to decrease the likelihood of grebe occurrence on a pond. I found no relationship between the occurrence of Horned Grebes and invertebrate abundance or pond water chemistry.

Although stable isotope analysis of pond food-webs gave an indication of grebe diet on breeding ponds, as well as indicating the freshwater origin of egg nutrients, it revealed little about grebe pond selection. I found that Horned Grebes appear to be generalist predators, exploiting locally available prey.

Management implications

It is clear from this study that borrow-pits in the Peace Parkland benefit Horned Grebes; in fact this region appears to be a grebe "hot-spot", attracting a greater frequency of occurrence of grebes than has been observed elsewhere. It has been noted that Horned Grebe populations tend to cluster in certain areas (Caldwell 2006), where high occupancy is unexplained by the number of suitable wetlands (other areas have suitable wetlands but a lower frequency of grebe occurrence). Pond construction, particularly in these Horned Grebe "hot-spots", appears to present a viable option for bolstering grebe population numbers. The question then arises as to what pond features most successfully attract nesting grebes? Table 5.1 summarizes study recommendations, including features relevant to pond construction and those that were significant in habitat selection models (Chapter 2); data presented for each parameter are the minimum 25th percentile and maximum 75th percentile as well as the mean median value observed over the study years (2003, 2007 and 2008). These quartiles were selected to capture the median 50% of the data for habitat features of ponds on which grebes occurred, to provide recommendations for constructing ideal Horned Grebe habitat. It is clear that landscape setting is important, as was observed by me and other researchers in Alberta and Saskatchewan (Gingras and Beyersbergen 2003, Beyersbergen and Gingras, unpublished data). Although there is a preference for ponds in open, agricultural areas, grebes will still use ponds in forested areas, in proportion to their availability on the landscape. Forested ponds, however, are more likely to have beaver activity. Pond size is another important factor; I found that Horned Grebes preferred large borrow-pits (grebes were more likely to occur on ponds 0.40 ha and greater; Table 5.1), but they will occur on ponds having a wide range of sizes (between 0.11 and 2.61 ha in 2007 and 2008) and broods were produced on ponds in different size categories in proportion to their general availability. Horned Grebes tend not to nest on very large wetlands, preferring ponds in the aforementioned range even when larger water bodies are available (Corrigan 2007, Moenting et al. 2007). Although not used in logistic regression analyses in Chapter 2, borrow-pits were variable in depth (between 0.70 m and 5.50 m based on a 29 pond subset). Horned Grebes were found on ponds at both extremes; the depth of these ponds does not appear to limit the occurrence of grebes, however, as grebes forage by diving, 0.7 m likely nears their minimum depth threshold needed. Human activities within and surrounding constructed ponds should be discouraged. Such activities include the addition of aerators (often associated with fish stocking), as well as the removal of emergent and riparian vegetation (observed at several locations). Horned Grebes do not appear to avoid ponds stocked with fish; however I only observed potential evidence (through SIA) of fish consumption by grebes in one pond; however, Horned Grebes in Europe prefer to nest on fishless lakes (Cramp and Simmons 1977). Because fish can greatly impact aquatic invertebrate prey of grebes (Zimmer et al. 2001), I recommend that fish stocking in borrow-pits be discouraged.

Although borrow-pits appear to benefit Horned Grebe populations, I caution against using these ponds as mitigation for regional wetland loss. A variety of dabbling and diving ducks use borrow-pits, however, a problem with borrow-pits in the Peace Parkland is that they can be quite deep (2.75 m on average but as deep as 5.50 m), dropping off quickly from the edges (although slope was not quantified). This shape of basin leaves little room for the growth of emergent vegetation, important for nest building material and anchorage, as well as shelter (Stedman 2000). I observed very few shorebirds on borrow-pits. This was likely due to this steep drop off and the resultant lack of shallow area for wading and foraging. Habitat value could potentially be increased substantially both for shorebirds and for dabblers and divers if gradual or terraced slopes were constructed, allowing for greater coverage of emergent vegetation and more shoreline structure and plant zonation (Zampella and Laidig 2003).

My study incidentally addressed the timing of pond surveys for grebes and other aquatic birds. Although it is common to use May data for population and breeding pair estimates, I feel that surveys at this time (particularly for northern areas) may overestimate bird abundances, as species richness is highest in May and there is a trend toward a higher frequency of occurrence of Horned Grebes in

May than in other months, likely due to use of ponds as stop-over sites during migration. Surveys of ponds in June (particularly late June) appear to give more reliable estimates of occurrence and chick production, as number of Horned Grebes, as well as total species richness, was fairly constant between June and July when chicks began to appear.

In conclusion, borrow-pits currently provide summer habitat for Horned Grebes and other aquatic birds in northwestern Alberta even though these ponds were not designed as wildlife habitat. The conservation value of these ponds could be enhanced through applying my research findings.

Literature Cited

Caldwell I. R. 2006. Use of waterfowl breeding survey data to estimate Horned Grebe populations in the Prairie Habitat Joint Venture. Canadian Wildlife Service. Unpublished report.

Corrigan R. 2007. Effectiveness of nest boxes in influencing population trends for Common Goldeneye (*Bucephala clangula*) and Bufflehead (*Bucephala albeola*) in the Buffalo Lake Moraine. M.Sc. Thesis, University of Alberta, Edmonton, Alberta, Canada.

Cramp S., and K. E. L. Simmons. 1977. Handbook of the birds of Europe the Middle East and North Africa: The birds of the Western Palearctic. **1**:722pp.

Gingras, B. A., and G. W. Beyersbergen. 2003. Horned Grebe use of artificial ponds in forested and agricultural areas of northwestern Alberta. Poster presentation: Society of Canadian Ornithologists.

Moenting A., L. Hamilton, C. Paszkowski, and R. Corrigan. 2007. Species richness patterns of aquatic birds in the Buffalo Lake Moraine, Alberta, in relation to wetland size, water level, and land-use types. Alberta Conservation Association, Edmonton, Alberta, Canada. 83pp.

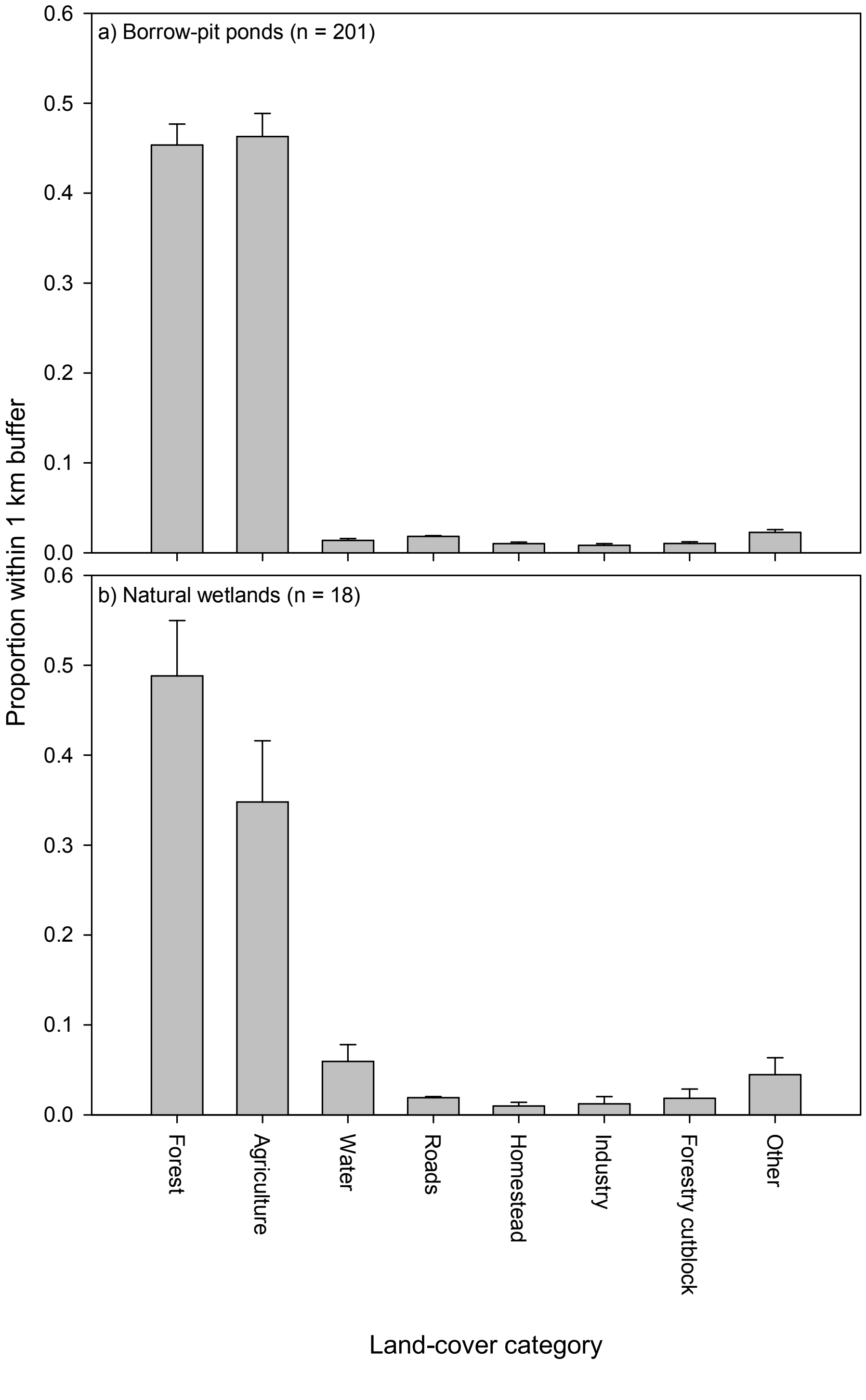
Stedman, S. J. 2000. Horned Grebe (*Podiceps auritus*). The birds of North America online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the birds of North America online: http://bna.birds.cornell.edu/bna/species/505, DOI:10.2173/bna.505.

Zampella R. A., and K. J. Laidig. 2003. Functional equivalency of natural and excavated coastal plain ponds. Wetlands **23**:860-876.

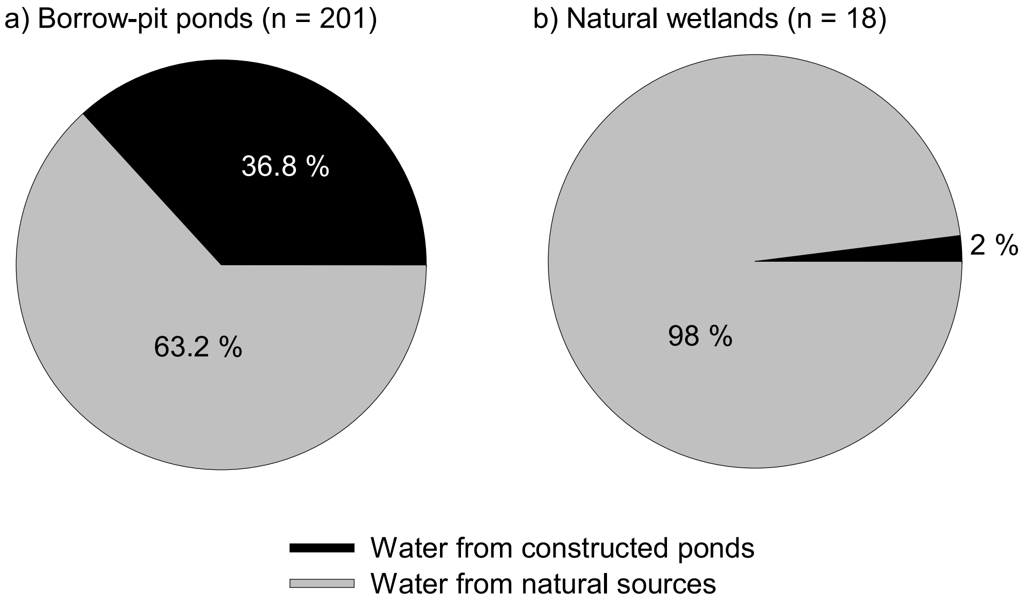
Zimmer K. D., M. A. Hanson, and M. G. Butler. 2001. Effects of fathead minnow colonization and removal on a Prairie wetland ecosystem. Ecosystems **4**:346-357.

Table 5.1: Summary of recommendations for Horned Grebe breeding pond construction. Data presented are the minimum 25^{th} – maximum 75^{th} percentile as well as the mean median values over 2003, 2007 and 2008 field data for constructed ponds occupied by Horned Grebes in the Peace Parkland, Alberta.

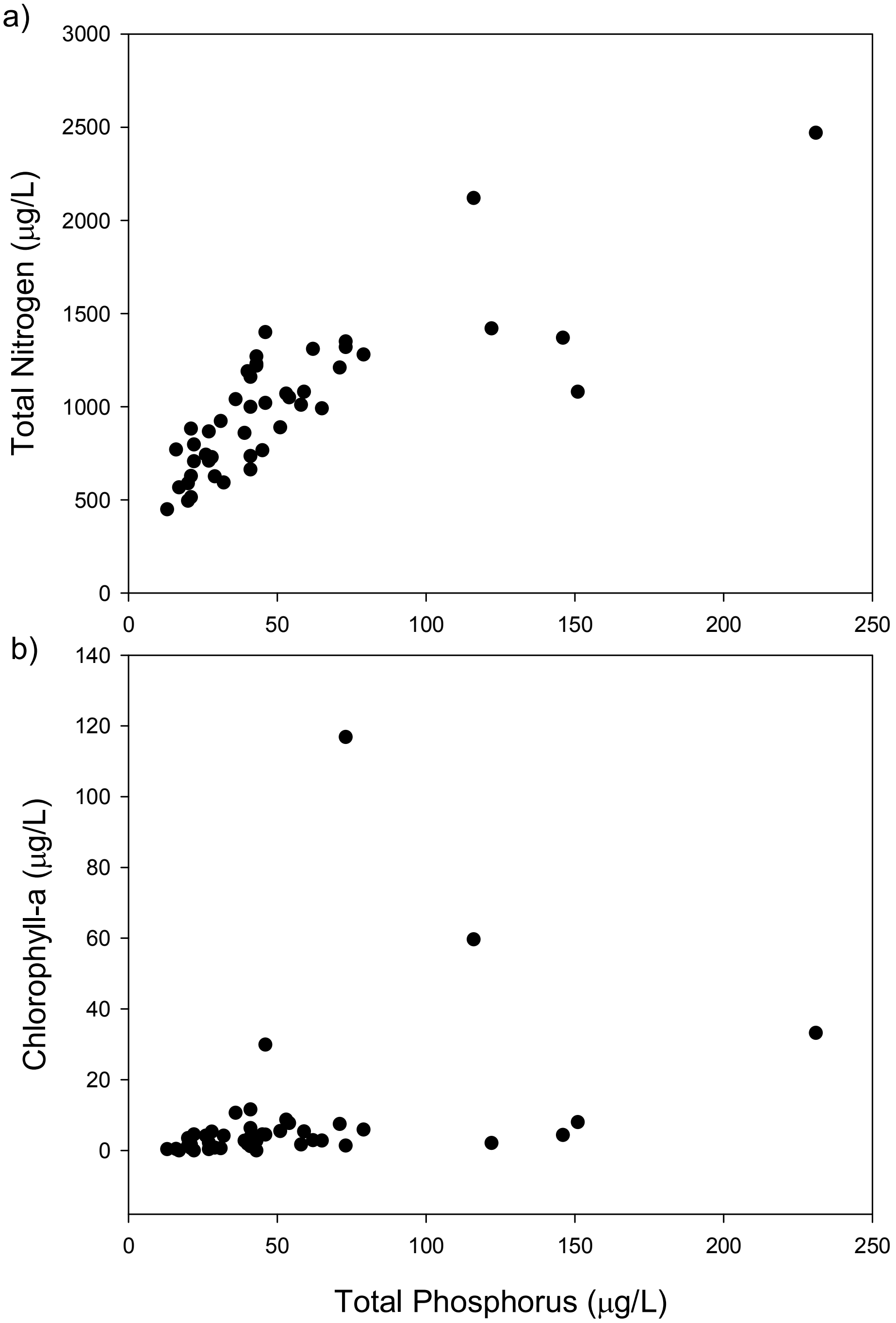
Parameter	**Recommendation**
Landscape	Agricultural; between 11 – 63% forest within 1 km (median: 28%)
Pond area	Between 0.40 – 0.81 ha (median: 0.57 ha)
Emergent vegetation	Covering 10 – 100% of perimeter (median: 73%)
Riparian vegetation	Covering 38 – 95% of perimeter (median: 80%)
Surrounding water	Not a relevant feature
Shoreline development	Exclude beavers
Human development	No fish stocking, aerators, pumps or docks



Appendix 2.1: Summary of proportions of land-cover categories measured for 1 km buffers surrounding a) 201 borrow-pit ponds and b) 18 natural wetlands in the Peace Parkland, Alberta. Proportions were calculated from aerial images in ArcGIS (see text). Error bars depict standard error. “Water” is combined natural and artificial sources of water; see Appendix 2.2 for distribution.



Appendix 2.2: Break-down of the proportion of water from constructed versus natural sources within 1 km buffers of a) 201 borrow-pit ponds and b) 18 natural wetlands in the Peace Parkland, Alberta.



Appendix 2.3: Relationships of limnological parameters measured in 2007 on 46 borrow-pit ponds in the Peace Parkland, Alberta. a) Total nitrogen versus total phosphorus, b) chlorophyll-a versus total phosphorus.

Appendix 2.4: Summary of the number of ponds supporting varying numbers of Horned Grebe chicks in 2007 versus 2008 on 201 constructed ponds in the Peace Parkland, Alberta.

		Max. number of chicks 2008						
		0	**1**	**2**	**3**	**4**	**5**	**9**
Max. number of chicks 2007	**0**	85	14	13	8	3	2	-
	1	3	2	1	1	1	-	-
	2	9	1	4	3	6	-	1
	3	9	3	-	4	1	2	-
	4	1	1	4	3	2	2	-
	5	1	-	3	3	2	-	-
	6	2	-	-		1	-	-

Appendix 2.5: Summary of environmental variables for 18 natural wetlands and 201 borrow-pit ponds in the Peace Parkland, Alberta.

	Natural (n = 18)		**Constructed (n = 201)**	
Parameter	**$\bar{x}$ ± SE**	**Range**	**$\bar{x}$ ± SE**	**Range**
Pond area (ha)	1.45 ± 0.34	0.13 - 5.31	0.64 ± 0.03	0.11 - 2.61
Distance from road to pond (m)	13.33 ± 2.89	1.00 - 51.00	37.84 ± 1.48	8.23 - 126.19
Proportion emergent vegetation	0.94 ± 0.04	0.20 - 1.00	0.75 ± 0.02	0 - 1.00
Proportion area covered by emergent vegetation	0.59 ± 0.06	0.05 - 0.95	0.24 ± 0.01	0 - 1.00
Proportion riparian vegetation	0.61 ± 0.05	0.10 - 0.95	0.67 ± 0.02	1 - 1.00
Rank of submersed aquatic vegetation (SAV)	4.11 ± 0.21	3 - 5	3.36 ± 0.07	1 - 5
Proportion forest within 1km	0.49 ± 0.06	0.06 - 0.98	0.45 ± 0.02	0.005 - 0.96
Proportion water within 1km	0.06 ± 0.02	0 - 0.25	0.01 ± 0.00	0 - 0.32
Distance to the nearest waterbody (m)	408.53 ± 76.77	13.88 - 980.80	497.68 ± 42.95	32.06 - 5830.66

Appendix 2.6: Summary of Buffalo Lake Moraine survey data for Horned Grebes divided into wetland size ranges (ha) for a) 1989, and b) 2003 (based on data from Corrigan 2007 and Moenting et al. 2007).

a) 1989

Size range (ha)	Number of ponds occupied	Number of ponds	Proportion of ponds occupied	Mean number of grebes/occupied pond
<0.05	2	126	0.02	1
0.05 - 0.10	6	289	0.02	1.67
0.10 - 0.50	24	454	0.05	1.83
0.50 - 2.50	56	261	0.21	1.86
2.50 - 12.50	10	57	0.18	2.1
>12.50	2	6	0.33	7
Totals	**100**	**1193**		

b) 2003

Size range (ha)	Number of ponds occupied	Number of ponds	Proportion of ponds occupied	Mean number of grebes/occupied pond
<0.05	0	276	0	0
0.05 - 0.10	1	140	0.01	1
0.10 - 0.50	17	206	0.08	1.53
0.50 - 2.50	26	88	0.3	1.96
2.50 - 12.50	7	24	0.29	3.86
>12.50	0	2	0	0
Totals	**51**	**736**		

Appendix 2.7: Summary of water chemistry data collected from 46 borrow-pits and 6 natural wetlands in the Peace Parkland, Alberta. All parameters were sampled in June 2008 except depth and Secchi depth which were sampled in July 2007. N/A for Secchi depth indicates that the disc was visible to the pond bottom.

Pond number	Constructed or natural	Total phosphorus (µg/L)	Cholorophyll-a (µg/L)	pH	Conductivity (µS)	Total nitrogen (µg/L)	Depth (m)	Secchi depth (m)	Forest within 1 km
4	C	65.00	2.79	8.65	240.00	991.00			0.45
11	C	41.00	6.33	7.75	240.00	999.00	5.50	0.90	0.18
12	C	29.00	0.78	7.75	815.00	626.00	2.50	0.78	0.10
13	C	22.00	0.00	7.80	915.00	797.00	4.15	3.25	0.07
15	C	58.00	1.67	8.75	790.00	1010.00	3.80	1.90	0.02
17	C	41.00	3.72	8.25	1365.00	735.00	3.70	2.23	0.06
21	C	116.00	59.68	8.65	1660.00	2120.00	4.65	1.90	0.01
25	C	21.00	1.01	8.05	535.00	628.00	3.60	1.88	0.01
36	C	51.00	5.46	8.20	910.00	889.00	3.10	0.73	0.04
44	C	53.00	8.68	8.85	760.00	1070.00			0.05
47	C	39.00	2.70	8.30	1740.00	859.00			0.20
50	C	79.00	5.88	7.75	665.00	1280.00	4.05	0.95	0.24
55	C	231.00	33.22	7.65	190.00	2470.00			0.10
77	C	17.00	0.00	8.10	1355.00	567.00	3.70	N/A	0.87
86	C	151.00	8.00	7.45	1440.00	1080.00	2.60	2.45	0.53
87	C	28.00	5.33	8.25	670.00	729.00	1.85	N/A	0.46
94	C	27.00	2.18	7.35	235.00	867.00	3.15	0.85	0.91
104	C	40.00	1.90	7.40	305.00	1190.00			0.76
107	C	73.00	1.33	7.50	750.00	1350.00			0.39
110	C	59.00	5.37	7.85	1085.00	1080.00	3.65	2.40	0.15
125	C	122.00	2.07	7.85	530.00	1420.00			0.13
134	C	73.00	116.84	8.95	530.00	1320.00			0.09
140	C	71.00	7.46	8.15	280.00	1210.00			0.04
149	C	26.00	4.15	8.20	595.00	742.00			0.77
161	C	22.00	4.54	8.00	410.00	707.00	1.30	N/A	0.92
163	C	20.00	3.47	8.70	195.00	589.00	0.90	N/A	0.76

Appendix 2.7 (continued)

Pond number	Constructed or natural	Total phosphorus (µg/L)	Cholorophyll-a (µg/L)	pH	Conductivity (µS)	Total nitrogen (µg/L)	Depth (m)	Secchi depth (m)	Forest within 1 km
168	C	32.00	4.16	8.00	1925.00	593.00	1.70	N/A	0.92
172	C	21.00	1.67	7.95	1355.00	882.00			0.90
178	C	13.00	0.36	8.20	375.00	449.00			0.93
194	C	54.00	7.72	8.10	760.00	1050.00			0.11
196	C	62.00	2.90	8.00	1085.00	1310.00			0.34
204	C	46.00	4.45	7.90	1195.00	1020.00			0.29
218	C	43.00	3.54	8.15	1990.00	1230.00			0.47
222	C	31.00	0.63	8.45	1675.00	923.00	2.50	N/A	0.14
243	C	146.00	4.34	7.80	1205.00	1370.00			0.91
244	C	20.00	1.28	8.45	1180.00	495.00	1.65	0.70	0.88
250	C	43.00	2.70	7.60	1215.00	1270.00	3.80	1.48	0.89
251	C	41.00	11.58	7.75	1250.00	1160.00			0.91
254	C	21.00	0.68	7.90	1525.00	514.00	1.30	0.98	0.89
256	C	36.00	10.62	9.00	1065.00	1040.00	2.85	1.75	0.92
305	C	41.00	1.18	8.20	1095.00	663.00	2.65	2.55	0.70
308	C	45.00	4.50	7.90	1280.00	766.00	1.60	1.16	0.67
310	C	16.00	0.43	8.10	1460.00	770.00	2.65	N/A	0.67
316	C	27.00	0.38	7.85	1640.00	710.00			0.63
319	C	46.00	29.88	8.05	810.00	1400.00			0.89
341	C	43.00	0.00	9.25	1050.00	1220.00	0.75	N/A	0.10
120	N	163.00	2.12	7.25	620.00	1010.00			0.13
338	N	49.00	2.24	8.30	415.00	1080.00			0.85
339	N	204.00	5.71	7.95	815.00	1680.00			0.98
340	N	160.00	0.27	7.30	1990.00	1350.00			0.59
345	N	471.00	0.00	9.25	395.00	2970.00			0.22
349	N	114.00	8.29	7.30	655.00	2970.00			0.45

Appendix 3.1: Summary of mean δ^{13}C, and δ^{15}N (unadjusted and baseline-corrected) of taxa used for stable isotope analysis in each pond a) occupied and b) unoccupied by Horned Grebes (Chapter 3). Means represent the combination of one to three individuals per taxon.

a) Ponds with Horned Grebes

Pond	**Taxon**	**δ^{15}N**	**Corrected δ^{15}N**	**δ^{13}C**
12	Hemiptera - Corixidae	3.91	2.78	-31.90
12	Coleoptera - *Dytiscus* - larval	4.95	3.82	-31.54
12	Hirudinea - Pharyngobdellida	4.82	3.70	-26.28
12	Odonata - Anisoptera	4.49	3.37	-29.58
12	Amphipoda - Gammaridae	2.58	1.45	-26.83
12	Coleoptera - *Dytiscus* - adult	4.06	2.93	-26.26
12	wood frog tadpole	1.82	0.69	-30.15
12	Gastropoda	1.13	0.00	-26.84
12	Horned Grebe egg albumen	8.86	7.73	-28.97
11	Amphipoda - Gammaridae	3.43	0.34	-26.41
11	Hemiptera - Corixidae	2.51	-0.57	-29.28
11	Ephemeroptera	2.34	-0.74	-26.68
11	Coleoptera - *Dytiscus* - larval	8.66	5.57	-26.56
11	Coleoptera - *Colymbetes*	5.11	2.03	-30.44
11	Coleoptera - *Dytiscus* - adult	6.48	3.40	-28.62
11	Trichoptera	1.96	-1.12	-25.81
11	Gastropoda	3.08	0.00	-25.54
11	Horned Grebe egg albumen	9.42	6.34	-26.84
87	Ephemeroptera	0.54	0.43	-32.18
87	Hirudinea - Rhynchobdellida	5.71	5.60	-26.01
87	Hirudinea - Pharyngobdellida	3.38	3.27	-28.21
87	Wood frog tadpole	1.40	1.29	-30.53
87	Hydrachnidia	3.70	3.59	-32.07
87	Trichoptera	-0.04	-0.15	-29.97
87	Amphipoda - Gammaridae	1.49	1.38	-28.16
87	Coleoptera - *Dytiscus* - larval	3.33	3.22	-30.63
87	Coleoptera - *Colymbetes*	2.44	2.33	-28.74
87	Odonata - Zygoptera	3.20	3.09	-28.39
87	Odonata - Anisoptera	4.19	4.08	-32.74
87	Gastropoda	0.11	0.00	-28.66
87	Horned Grebe egg albumen	8.28	8.17	-28.52
15	Odonata - Anisoptera	4.31	1.24	-23.01
15	Coleoptera - *Dytiscus* - larval	6.31	3.24	-26.12
15	Ephemeroptera	3.65	0.58	-24.14
15	Hirudinea - Rhynchobdellida	6.49	3.42	-22.09
15	Amphipoda - Gammaridae	4.58	1.51	-22.84
15	Gastropoda	3.07	0.00	-25.32
15	Coleoptera - *Dytiscus* - adult	5.75	2.68	-26.55
15	Brook stickleback	9.73	6.66	-26.00
15	Horned Grebe egg albumen	9.68	6.61	-22.95

Appendix 3.1a (continued)

Pond	**Taxon**	**$\delta^{15}N$**	**Corrected $\delta^{15}N$**	**$\delta^{13}C$**
36	Hirudinea - Pharyngobdellida	6.18	2.84	-25.94
36	Amphipoda - Gammaridae	3.72	0.37	-26.21
36	Coleoptera - Gyrinidae	4.71	1.37	-30.68
36	Trichoptera	3.37	0.03	-28.18
36	Hydrachnidia	5.55	2.21	-23.97
36	Odonata - Zygoptera	5.53	2.19	-26.12
36	Coleoptera - *Hydroporus superioris*	4.34	1.00	-27.44
36	Dytiscidae - *Liodessus affinis*	11.40	8.05	-22.34
36	Hemiptera - Corixidae	1.66	-1.68	-35.39
36	Gastropoda	3.34	0.00	-26.78
36	Horned Grebe egg albumen	10.61	7.27	-24.62
36	Pearl dace	7.16	3.81	-28.64
17	Amphipoda - Gammaridae	4.82	0.32	-27.65
17	Hirudinea - Pharyngobdellida	7.10	2.60	-28.59
17	Trichoptera	3.52	-0.98	-27.33
17	Coleoptera - *Dytiscus* - adult	6.40	1.90	-28.60
17	Coleoptera - *Colymbetes*	4.87	0.37	-29.27
17	Gastropoda	4.50	0.00	-27.36
17	Horned Grebe egg albumen	11.59	7.09	-28.00
341	Odonata - Zygoptera	4.64	2.51	-30.59
341	Coleoptera - *Dytiscus* - larval	3.26	1.13	-29.85
341	Odonata - Anisoptera	3.42	1.30	-30.28
341	Hemiptera - Gerridae	3.69	1.57	-27.88
341	Wood frog tadpole	2.72	0.59	-29.12
341	Gastropoda	2.12	0.00	-27.19
341	Horned Grebe egg albumen	7.83	5.70	-26.99

Appendix 3.1 (continued)

b) Ponds without Horned Grebes

Pond	**Taxon**	**$\delta^{15}N$**	**Corrected $\delta^{15}N$**	**$\delta^{13}C$**
77	Odonata - Zygoptera	4.08	4.69	-27.68
77	Trichoptera	0.04	0.65	-29.38
77	Amphipoda - Gammaridae	0.50	1.11	-26.83
77	Wood frog tadpole	1.90	2.51	-30.45
77	Odonata - Anisoptera	2.39	3.00	-26.91
77	Coleoptera - *Dytiscus* - larval	1.50	2.11	-29.83
77	Gastropoda	-0.61	0.00	-28.49
55	Hirudinea - Pharyngobdellida	6.44	1.19	-28.40
55	Odonata - Zygoptera	7.51	2.26	-29.95
55	Amphipoda - Gammaridae	5.83	0.58	-28.72
55	Coleoptera - *Colymbetes*	6.16	0.91	-30.18
55	Trichoptera	4.65	-0.60	-29.26
55	Coleoptera - *Dytiscus* - larval	6.98	1.73	-30.65
55	Coleoptera - *Dytiscus* - adult	5.56	0.31	-27.10
55	Gastropoda	5.25	0.00	-28.16
86	Coleoptera - *Dytiscus* - larval	2.57	3.11	-30.97
86	Amphipoda - Gammaridae	1.52	2.06	-28.87
86	Odonata - Anisoptera	1.94	2.48	-32.20
86	Trichoptera	0.12	0.66	-30.83
86	Hemiptera - Gerridae	3.59	4.13	-27.37
86	Coleoptera - *Dytiscus* - adult	3.78	4.32	-30.26
86	Wood frog tadpole	1.02	1.56	-33.87
86	Odonata - Zygoptera	3.42	3.96	-32.64
86	Gastropoda	-0.54	0.00	-30.03
94	Odonata - Anisoptera	3.26	0.89	-35.27
94	Hemiptera - Gerridae	3.26	0.89	-30.36
94	Odonata - Zygoptera	4.38	2.01	-33.61
94	Trichoptera	4.84	2.46	-35.64
94	Hemiptera - Notonectidae	4.41	2.04	-34.11
94	Amphipoda - Gammaridae	2.14	-0.23	-30.53
94	Hemiptera - Corixidae	2.73	0.36	-33.18
94	Gastropoda	2.37	0.00	-34.69
94	Brook stickleback	7.62	5.25	-36.98
13	Odonata - Anisoptera	3.82	0.68	-29.80
13	Hirudinea - Gnathobdellida	5.22	2.08	-29.10
13	Amphipoda - Gammaridae	2.59	-0.55	-29.44
13	Coleoptera - *Dytiscus* - adult	6.90	3.76	-28.51
13	Trichoptera	2.07	-1.07	-27.45
13	Coleoptera - *Colymbetes*	4.28	1.14	-28.90
13	Gastropoda	3.14	0.00	-28.90

Appendix 3.1b (continued)

Pond	**Taxon**	**$\delta^{15}N$**	**Corrected $\delta^{15}N$**	**$\delta^{13}C$**
21	Coleoptera - *Dytiscus* - adult	6.16	6.16	-30.54
21	Odonata - Zygoptera	6.19	6.19	-29.32
21	Hemiptera - Corixidae	3.65	3.65	-27.07
21	Gastropoda	0.00	0.00	-24.77
21	Coleoptera - *Colymbetes*	5.18	5.19	-30.99
21	Trichoptera	4.88	4.89	-29.68
21	Hirudinea - Gnathobdellida	6.25	6.26	-28.32
21	Hirudinea - Pharyngobdellida	6.21	6.22	-29.20
21	Amphipoda - Gammaridae	4.08	4.08	-28.30
50	Coleoptera - *Dytiscus* - larval	3.72	1.28	-33.23
50	Hemiptera - Gerridae	6.47	4.03	-25.53
50	Amphipoda - Gammaridae	2.63	0.20	-28.42
50	Odonata - Zygoptera	5.71	3.27	-31.81
50	Trichoptera	3.42	0.99	-27.90
50	Ephemeroptera	1.21	-1.22	-31.24
50	Odonata - Anisoptera	4.68	2.25	-31.82
50	Gastropoda	2.43	0.00	-27.56
50	Brook stickleback	8.77	6.33	-29.54

Appendix 4.1: Summary of occurrences of aquatic birds (the number of each species on each pond type) on 91 agricultural (0-33.3% forest within a 500 m buffer), 44 mixed (33.4-66.6% forest) and 65 forested (66.7-100% forest) borrow-pit ponds in the Peace Parkland, Alberta in May, June, July and August 2007.

	May				**June**				**July**				**August**			
Common name	Agriculture	Mixed	Forested	Total	Agriculture	Mixed	Forested	Total	Agriculture	Mixed	Forested	Total	Agriculture	Mixed	Forested	Total
American Coot	11	1	1	13	6	4	0	10	13	6	1	20	8	4	1	13
American Wigeon	8	12	10	30	5	5	8	18	1	4	1	6	1	2	1	4
Barrow’s Goldeneye	0	1	3	4	0	1	1	2	0	0	0	0	0	0	0	0
Black Tern	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Blue-winged Teal	6	3	3	12	5	3	4	12	1	1	1	3	0	0	0	0
Bufflehead	23	25	38	86	8	20	33	61	16	19	30	65	2	3	1	6
Canada Goose	0	0	4	4	1	1	0	2	4	2	1	7	1	0	1	2
Canvasback	3	8	4	15	2	3	2	7	7	3	3	13	5	5	3	13
Common Goldeneye	7	5	6	18	1	2	3	6	5	0	4	9	2	0	0	2
Common Snipe	0	2	3	5	1	0	0	1	0	0	0	0	0	0	2	2
Common Tern	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Gadwall	0	0	0	0	1	1	0	2	1	0	0	1	0	0	1	1
Green-winged Teal	1	8	14	23	1	1	7	9	0	0	0	0	1	2	1	4
Hooded Merganser	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2
Horned Grebe	54	21	25	100	46	19	19	84	42	17	13	72	6	1	0	7
Lesser Scaup	23	8	2	33	25	9	5	39	15	3	0	18	21	7	6	34
Lesser Yellowlegs	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1
Mallard	22	11	13	46	9	2	1	12	6	1	1	8	7	7	2	16
Northern Pintail	1	0	0	1	0	0	0	0	0	0	0	0	3	0	0	3
Northern Shoveler	10	12	3	25	6	1	3	10	0	2	1	3	2	2	0	4
Redhead	2	1	1	4	1	1	1	3	0	0	1	1	0	1	0	1
Ring-necked Duck	8	10	21	39	3	4	16	23	5	5	7	17	6	8	14	28
Ruddy Duck	2	2	1	5	2	2	0	4	0	1	0	1	3	1	1	5
Solitary Sandpiper	0	1	0	1	1	1	0	2	0	0	0	0	2	0	0	2
Sora	0	0	0	0	2	0	1	3	1	0	0	1	0	0	0	0
Spotted Sandpiper	0	0	0	0	0	0	0	0	0	0	0	0	6	0	2	8
Surf Scoter	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 4.2: Summary of mean aquatic bird species abundance on 91 agricultural (0-33.3% forest within a 500 m buffer), 44 mixed (33.3-66.6% forest) and 65 forested (66.6-100% forest) borrow-pit ponds in the Peace Parkland, Alberta in May, June, July and August 2007.

	May			**June**			**July**			**August**		
Common name	Agriculture	Mixed	Forested	Agriculture	Mixed	Forested	Agriculture	Mixed	Forested	Agriculture	Mixed	Forested
American Coot	0.20	0.02	0.02	0.08	0.09	0.00	0.25	0.16	0.02	0.11	0.16	0.02
American Wigeon	0.18	0.50	0.23	0.08	0.20	0.15	0.01	0.14	0.02	0.01	0.25	0.02
Barrow's Goldeneye	0.00	0.02	0.05	0.00	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Black Tern	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blue-winged Teal	0.16	0.16	0.08	0.08	0.11	0.08	0.01	0.05	0.02	0.00	0.00	0.00
Bufflehead	0.40	1.23	1.20	0.16	0.59	1.00	0.21	0.45	0.60	0.07	0.18	0.09
Canada Goose	0.00	0.00	0.09	0.11	0.05	0.00	0.21	0.00	0.03	0.21	0.00	0.02
Canvasback	0.07	0.59	0.34	0.02	0.09	0.03	0.13	0.16	0.05	0.14	0.30	0.32
Common Goldeneye	0.14	0.16	0.20	0.01	0.07	0.09	0.11	0.00	0.06	0.03	0.00	0.00
Common Snipe	0.00	0.09	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Common Tern	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gadwall	0.00	0.00	0.00	0.01	0.05	0.00	0.01	0.00	0.00	0.00	0.00	0.02
Green-winged Teal	0.02	0.23	0.34	0.01	0.05	0.17	0.00	0.00	0.00	0.02	0.05	0.02
Hooded Merganser	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00
Horned Grebe	1.12	0.84	0.65	0.70	0.59	0.34	0.64	0.47	0.28	0.08	0.02	0.00
Lesser Scaup	0.82	0.73	0.03	0.84	0.70	0.29	0.21	0.18	0.00	0.29	0.30	0.11
Lesser Yellowlegs	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00
Mallard	0.38	0.55	0.35	0.19	0.07	0.03	0.07	0.02	0.02	0.16	0.50	0.05
Northern Pintail	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Northern Shoveler	0.35	0.59	0.09	0.09	0.05	0.08	0.00	0.05	0.02	0.03	0.05	0.00
Redhead	0.03	0.05	0.05	0.03	0.05	0.05	0.00	0.00	0.02	0.00	0.02	0.00
Ring-necked Duck	0.24	0.89	1.40	0.10	0.20	0.71	0.19	0.18	0.23	0.09	0.36	0.45
Ruddy Duck	0.04	0.09	0.09	0.03	0.09	0.00	0.00	0.05	0.00	0.03	0.07	0.03
Solitary Sandpiper	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.04	0.00	0.00
Sora	0.00	0.00	0.00	0.02	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00
Spotted Sandpiper	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.05
Surf Scoter	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00