University of Alberta

EFFECTIVENESS OF NEST BOXES IN INFLUENCING POPULATION TRENDS FOR COMMON GOLDENEYE (*Bucephala clangula*) AND BUFFLEHEAD (*B. albeola*) IN THE BUFFALO LAKE MORAINE

By

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

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ABSTRACT

Waterfowl population declines associated with loss and alterations of breeding habitat have been well documented at a variety of spatial scales. However, intensive management techniques are often employed to mitigate loss or scarcity of key habitat features. One such technique involves provision of nest boxes for cavity-nesting waterfowl. Beginning in 1989, nest boxes were erected in the Buffalo Lake Moraine, of east central Alberta, to increase populations of Common Goldeneye (*Bucephala clangula)* and Bufflehead (*Bucephala albeola).* Using data collected during a 16-year period (1989 – 2004) and a 2-year nest box manipulation experiment (2004 – 2005), I assessed the effectiveness of using nest boxes to increase populations of Common Goldeneye and Bufflehead. Nest boxes can increase populations of Common Goldeneye and Bufflehead. Often, wildlife management initiatives are undertaken for the purpose of increasing desired species abundance without regard to potential negative impacts on other wildlife species. Therefore, I compared waterfowl and waterbird assemblages when densities of Common Goldeneye and Bufflehead were low (1989) and high (2003). I found waterfowl and waterbird communities to be similar between 1989 and 2003 within the Buffalo Lake Moraine.

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TABLE OF CONTENTS

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

LIST OF TABLES

Chapter 2

Chapter 3

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Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

LIST OF FIGURES

Chapter 2

Chapter 3

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LIST OF APPENDICES

Chapter 2

Chapter 3

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CHAPTER 1

General Introduction and Thesis Overview

BACKGROUND AND THESIS RATIONALE

The prairie pothole region (PPR), located within parts of South and North Dakota, Iowa, Minnesota, Montana, Manitoba, Saskatchewan and Alberta, is recognized as the single most important region for breeding waterfowl in North America (Batt et al. 1989). Although this region encompasses approximately 10% of all suitable waterfowl breeding habitat in North America, it accounts for greater than 50% of annual continental waterfowl production (Batt et al. 1989). Located in the northwestern portion of the prairie pothole region, the aspen parkland eco-region of central Alberta has undergone large-scale conversion of native vegetation into agricultural crops and pasture. The aspen parkland eco-region is now characterized by small groves of willow (*Salix spp.),* aspen (*Poplus tremuloides)* and balsam poplar (*Poplus balsmifera)* often within riparian zones, intermixed with small residual patches of native rough fescue *(Festuca scrabrella)* (Bailey and Wroe 1974). Approximately 5% of the land base remains occupied by plant communities comparable to those found prior to European settlement (Van Tighem 1993). Agricultural encroachment is cited as the principal factor responsible for habitat loss and continued landuse changes throughout this broad geographic region (Kantrud et al., 1989).

Population declines of waterfowl in the PPR have been documented at a variety of spatial scales and are often associated with the direct loss of wetlands and alteration of associated habitats (Bellrose 1980, NAWMP 1986, Baldassarre and Bolen 1994). In addition to effects of direct habitat loss, changes in the structure of predator communities or efficiencies of predators that eat waterfowl or depredate nests, associated with highly altered landscapes, may also represent significant threats to the persistence of waterfowl populations in North America (Duebbert and Lokemoen 1980, Greenwood et. al 1995, Philips et. al 2003). In response to habitat

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loss and increased nest predation, wildlife managers often implement conservation programs aimed at enhancing waterfowl populations. One such measure, used to mitigate habitat loss and predation on nesting waterfowl, is the provision of nest boxes for cavity nesting waterfowl (Bellrose 1980, Savard 1988, Poysa and Poysa 2002). Nest boxes have been widely and successfully used to increase populations of Wood Ducks *(Aix sponsa)* in areas where natural nesting habitats have been destroyed or altered (Bellrose 1980). The provision of nest boxes has also been linked to increased productivity and subsequent increases in local populations of *Bucephala spp.* (Coulter 1979, Dennis and Dow 1984, Savard 1988, Poysa and Poysa 2002).

While nest boxes can effectively enhance local populations of *Bucephala spp.,* there remains some concern that population increases of *Bucephala spp.,* may alter the overall structure of waterfowl and waterbird communities. Intra-specific and inter-specific territoriality and aggression are well documented for both Common Goldeneye *(Bucephala clangula)* and Bufflehead *(Bucephala albeola)* (Gautier 1993, Eadie *et al.* 1995). Territorial behaviour in Common Goldeneye and Bufflehead drakes typically occurs during the spring mating season and into early incubation when individual males establish and actively defend defined areas (Savard 1984). It has been suggested that inter-specific aggression involving *Bucephala spp.,* has the potential to affect community structure of waterfowl and that provision of nest boxes for *Bucephala spp.* may have deleterious effects on other waterfowl species.

Beginning in 1989, an extensive set of nest boxes were deployed in the Buffalo Lake moraine region of central Alberta in response to the perceived lack of available natural cavities suitable for Common Goldeneye and Bufflehead. Nest boxes were deployed in conjunction with a long-term waterfowl and wetland monitoring program under the North American Waterfowl Management Plan (NAWMP). Implementing a nest box program concurrently with a monitoring program allowed measurement of nest box effectiveness to enhance populations of targeted species, while examining whether increases in *Bucephala spp.* result in changes to waterfowl community structure. Through analysis of long-term waterfowl

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and waterbird monitoring data and a nest box manipulation experiment, I evaluated the (1) effectiveness of nest boxes and (2) examined effects on waterfowl and waterbird communities. These 2 objectives are described below.

Objective I: To evaluate the efficacy of nest boxes for increasing breeding populations of cavity-nesting waterfowl in central Alberta (Chapter 2).

Beginning in 1989, the Alberta Fish and Wildlife Division initiated a long-term waterfowl and wetland monitoring program in the Buffalo Lake Moraine. Biennial surveys were conducted through 2003 in response to activities undertaken by the Alberta NAWMP partnership to monitor waterfowl and waterbird populations within this high priority landscape (Allen 1989). This long-term data set allowed me to analyze population trends and evaluate the effectiveness of nest boxes for increasing populations of *Bucephala spp.*. My analysis and evaluation is based on data from; 1) the previously described long-term waterfowl and wetland monitoring program in the Buffalo Lake Moraine (1989 – 2003) and 2) an experimental nest box manipulation conducted during the 2004 and 2005 breeding seasons.

To assess effectiveness of nest boxes in increasing breeding populations of Common Goldeneye and Bufflehead, my approach was 4-fold. First, I describe variation in the abundance of waterfowl and waterbird species over a 16-year period at the regional scale (i.e. Stratum 26 of the North American spring waterfowl breeding surveys) and at the local level (i.e. Buffalo Lake Moraine). These analyses compared temporal variation in the abundance of cavity-nesting waterfowl with other species of waterfowl and waterbirds. Second, I examined the relationship between waterfowl and waterbird abundance and wetland density at both the regional and local scale. These analyses compared the relationship of wetland density and abundance of cavity-nesting waterfowl compared to this relationship for other waterfowl and waterbird species. Third, I quantified variation in the occupancy of nest boxes over a 16-year period in the Buffalo Lake Moraine to determine if changes in *Bucephala spp.* populations during that time period paralleled nestbox occupancy patterns. Finally, I conducted a 2-year experimental manipulation of nest boxes to test the

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hypothesis that Common Goldeneye and Bufflehead populations in the Buffalo Lake Moraine are limited by availability of nest cavities.

At a regional scale (Stratum 26), I predicted that the majority of waterfowl species would decline during the study period, primarily due to a landscape-level decrease in wetland abundance. I also predicted that the majority of waterfowl and waterbird species would decline at the local scale (Buffalo Lake Moraine), again due to declining wetland abundance. I anticipated that occupancy rates of nest boxes by Common Goldeneye and Bufflehead would initially increase as newly "recruited" birds located boxes and would subsequently stay high as birds continued to use and depend upon nest boxes year after year due to philopatric tendencies of female *Bucephala spp.* Lastly, I predicted that the closure of nest boxes would not affect the number of pairs occupying wetlands, but would reduce the mean number of broods in areas where nest boxes were closed compared to adjacent areas where nest boxes remained open.

Objective II: To document if changes in the abundance of Common Goldeneye and Bufflehead mediated by deployment of next boxes influence the overall structure of waterfowl and waterbird communities in the Buffalo Lake Moraine (Chapter 3).

Wildlife managers apply a suite of techniques to enhance populations of priority waterfowl species, including deploying next boxes. While many studies have shown that this can increase populations of focal species, few studies have evaluated if increases in focal species can alter the overall structure of waterfowl communities. Through the analysis of waterfowl and waterbird community data, and behavioral observation studies, I examined potential impacts of nest box programs on non-targeted aquatic bird species. Specifically, I had 3 primary objectives. First, using presence/absence records of breeding waterfowl and waterbird pairs and the presence/absence of waterfowl and waterbird broods, I tested for relationships between waterfowl and waterbird communities and environmental variables in the Buffalo Lake Moraine. Second, I tested for concordance between the assemblages of

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waterfowl and waterbird communities on study area wetlands with low densities of Common Goldeneye and Bufflehead (in 1989, prior to nest box program) and with increased densities of Common Goldeneye and Bufflehead (in 2003, after nest box program had been in place for 15 years). Third, I conducted focal animal sampling of Common Goldeneye and Bufflehead behavior in the Buffalo Lake Moraine to examine intra and inter-specific aggression involving Common Goldeneye and Bufflehead, which may contribute to patterns in community structure.

I predicted that waterfowl and waterbird communities respond as foraging guilds (i.e. dabblers vs. divers) and will reflect environmental variables, which are associated with specific feeding and nesting requirements. Secondly, I predicted that waterfowl and waterbird communities on Buffalo Lake Moraine wetlands have changed in response to increased densities of Common Goldeneye and Bufflehead. Lastly, I predicted that I would observe aggression by Common Goldeneye and Bufflehead directed towards other species of waterfowl and waterbirds, which might explain alterations in community structure.

In Chapter 4, I summarize the overall findings of my research that assessed the effectiveness of nest boxes in increasing populations of Common Goldeneye, and the extent that increases in populations of Common Goldeneye and Bufflehead altered the structure of waterfowl communities in the Buffalo Lake Moraine over the last decade. Lastly, I recommend a number of actions that could expand the nest box program in central Alberta and identify additional research needs and direction.

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CHAPTER 2

The efficacy of nest boxes for increasing populations of Common Goldeneye (*Bucephala clangula*) and Bufflehead (*B. albeola*) in the Buffalo Lake Moraine.

INTRODUCTION

Population declines of waterfowl are well documented at the local, regional and continental scales (Bellrose 1980, NAWMP 1986). These declines are often associated with direct loss or alteration of habitat due primarily to the loss of wetlands through expansion or intensification of agriculture (NAWMP 1986, Baldassarre and Bolen 1994). While habitat loss and alteration can negatively impact waterfowl during all life stages, population declines are most often associated with loss or destruction of breeding habitat (Baldassarre and Bolen 1994). In addition to direct habitat loss, changes in the structure of predator communities or efficiencies of predators associated with highly altered landscapes also represent significant threats to the persistence of North American waterfowl populations (Duebbert and Lokemoen 1980, Greenwood et. al 1995, Philips et. al 2003).

The prairie pothole region of North America was formed as a result of glacial activity during the Pleistocene and includes parts of South and North Dakota, Iowas, Minnesota, Montana, Manitoba, Saskatchewan and Alberta (Baldasarre and Bolen 1994, Mitsch and Gosselink 2000). This 780,000 km^2 area is considered the most important region for breeding waterfowl in North America (Batt et al. 1989, Baldasarre and Bolen 1994). Although this region comprises approximately 10% of all suitable waterfowl breeding habitat in North America, it accounts for greater than 50% of annual continental waterfowl production (Batt et al. 1989). Direct loss of wetland habitat in the prairie pothole region has been substantial, and drainage and in-filling of waterbodies have resulted in the estimated loss of over 50% of wetland habitat in the prairie pothole region of the United States since European colonization (Dahl 1990). A Canadian study, that monitored 10,000 wetlands from 1981 – 1985,

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found that over 50% of the wetland basins had been degraded (Turner et al. 1987). Despite their continental importance, 90% of the remaining wetlands in the prairie pothole region may have also been negatively impacted (Nerassen and Nelson 1999). Although annual wetland loss has slowed in recent decades, the continued loss of wetlands and the intensification of agricultural use of associated uplands represent significant concerns threatening ecological functions associated with wetland habitats (Dailey 1995, Dahl 2000). In addition, for cavity-nesting birds, the removal of large trees and standing dead trees or snags from riparian zones can reduce the availability of nesting sites.

Nest boxes have been widely and successfully used to increase populations of Wood Ducks *(Aix sponsa)* in areas where natural nesting sites have been destroyed or altered (Bellrose 1990). The provision of artificial nest boxes has also been linked to increased productivity and subsequent local population increases of *Bucephala* species (Coulter 1979, Dennis and Dow 1984, Savard 1988, Poysa and Poysa 2002). The extent that nest boxes increase productivity of cavity-nesting waterfowl depends, in part, on the extent that the occurrence of natural cavities limits reproductive success. For example, Gauthier and Smith (1987) found that addition of nesting boxes did not increase local breeding populations of Bufflehead *(Bucephala albeola)* in the Cariboo Parklands of British Columbia because the availability of naturally occurring flicker cavities was not limiting population growth.

Beginning in 1989, nest boxes were extensively deployed in the Buffalo Lake moraine region of central Alberta in response to the perceived lack of natural nesting cavities for Common Goldeneye *(B. clangula)* and Bufflehead (Potter 2004). While detailed analyses of waterfowl populations in the Buffalo Lake Moraine have not been completed, anecdotal evidence suggests that densities of both species have increased since the late 1980's whereas, densities of other waterfowl species such as Mallard *(Anas platyrhynchos)*, Blue-winged Teal *(Anas discors)*, Gadwall *(Anas streptera)*, Canvasback *(Aythya valisineria)*, Redhead *(Aythya americana)* and Lesser

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Scaup *(Aythya affinis)* appear to have either remained stable or declined during that same time period (Murphy *et. al* 2004).

The objective of my study was to evaluate the effectiveness of nest box programs for increasing breeding populations of cavity-nesting waterfowl in central Alberta. To assess the effectiveness of the provision of nest boxes to increase breeding populations of Common Goldeneye and Bufflehead, my study was 4-fold. First, I describe variation over a 16-year period in the abundance of waterfowl and waterbird species at the regional scale (i.e. within Stratum 26 at 90,280 km^2) of the United States Fish and Wildlife Service (USFWS) and Canadian Wildlife Service (CWS) spring waterfowl surveys and at the local level (i.e. within the Buffalo Lake Moraine at 1,295 km^2). I completed these analyses to compare temporal variation in the abundance of cavity-nesting waterfowl with other species of waterfowl and waterbirds. Second, I examined the relationship between waterfowl and waterbird abundance and wetland density at both the regional and local scales. I completed these analyses to compare the relationship of wetland density to abundance of cavity-nesting waterfowl with the relationship for other waterfowl and waterbird species. Third, I quantified variation in the occupancy of nest boxes over a 16-year period in the Buffalo Lake Moraine to determine if changes in *Bucephala spp.* populations during that time period paralleled nest box occupancy patterns. Fourth, I completed a 2-year nest box exclosure experiment to test the hypothesis that Common Goldeneye and Bufflehead populations in the Buffalo Lake Moraine are limited by the availability of nest cavities.

At the largest scale (Stratum 26), I predicted that the majority of waterfowl species including Common Goldeneye and Bufflehead have declined since 1989, primarily driven by a landscape-level decline in wetland abundance. I predicted that the majority of waterfowl and waterbird species have declined at the local scale (Buffalo Lake Moraine) again driven primarily by climatic conditions. I expected that occupancy rates of nest boxes would initially increase as newly "recruited" birds located boxes and would stay high as birds continued to use and depend upon nest

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boxes year after year. Lastly, I predicted that the experimental closure of nest boxes would not affect the number of pairs occupying wetlands in the spring, due to the fidelity of these species to breeding sites. However, I predicted the closure of nest boxes would reduce the mean number of broods in areas where nest boxes were closed compared to adjacent areas where nest boxes remained open.

METHODS

Study Area

Using existing data sets, I summarized spring breeding waterfowl and waterbird populations between 1989 – 2004 at a local and regional scale. Field work and data analysis were completed for a region of central Alberta that encompassed the Buffalo Lake Moraine and Stratum 26, an area where spring waterfowl populations have been monitored by the United States Fish and Wildlife Service (USFWS) and Canadian Wildlife Service (CWS) (Figure 2.1). To describe temporal variation of breeding waterfowl at a regional level, I quantified waterfowl population trends in Stratum 26 using data obtained through the United States Fish and Wildlife Service Division of Migratory Bird Management (http://www.fws.gov/birddata/databases/mas/maydb.html). To describe trends of breeding waterfowl and waterbird populations at a local scale, I used data collected through the Buffalo Lake Waterfowl and Wetland surveys (Murphy *et al* 2004). These data were collected by the Province of Alberta and the Alberta Conservation Association between 1989-2004 (Alberta Sustainable Resource Development, Fish and Wildlife Division, unpublished data). I was personally involved in data collection in the Buffalo Lake Moraine during the 2003 and 2004 waterfowl and waterbird surveys.

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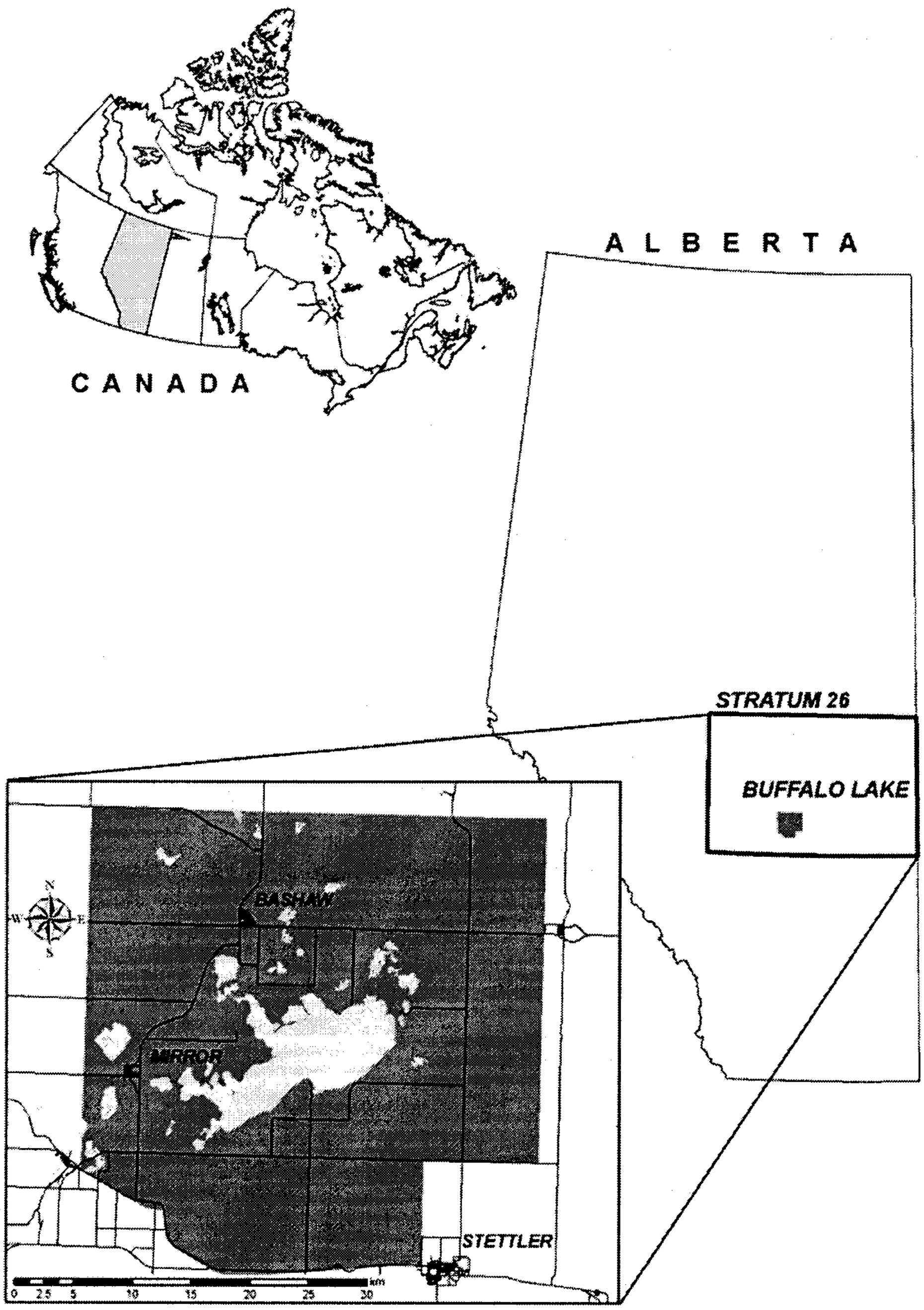

Figure 2.1: Location of the Buffalo Lake Moraine waterfowl and wetland surveys and Stratum 26 of the United States Fish and Wildlife Service and Canadian Wildlife Service spring waterfowl surveys in central Alberta.

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Analysis of regional and local waterfowl and waterbird breeding populations

Survey methods

Stratum 26

Detailed spring surveys are conducted annually by federal, state and provincial waterfowl managers to estimate the waterfowl population on the spring breeding grounds, which in turn are used in the development of hunting regulations and harvest limits throughout North America (Bellrose 1980). Surveys are conducted using low-level fixed-wing aircraft along east–west transects which cover approximately 5.2 million km^2 of the primary continental spring breeding grounds (USFWS 2004). Each transect extends 200 m north and south from a line centered in this strip within which observers identify and count waterfowl by species and abundance and wetland numbers. Within the PPR, fixed-winged surveys are verified and ground-truthed for visibility bias by ground crews who replicate survey effort on portions of the transects within 24 hours of survey flights (Bellrose 1980).

In addition to surveying spring waterfowl populations, the USFWS and CWS also calculate population estimates for American Coot *(Fulica americana)* during the spring waterfowl surveys. Estimates of spring waterfowl and American Coot populations within Stratum 26 were obtained from the United States Fish and Wildlife Service, Migratory Bird Division (http://www.fws.gov/birddata/databases/mas/maydb.html) (Appendix 2.1). Following standard operating procedures for aerial waterfowl breeding ground population and habitat surveys (Anonymous 1987), waterfowl species are observed, identified and subsequently recorded in the following manner:

a) Lone Drake (LD): single male with no associated hen (recorded as "No(s)"for all species).
b) Lone Hen (H): single female with no associated male. Recorded for Ruddy Duck (*Oxyura jamaicensis*), Redhead (*Aythya americana*), Ring-necked Duck (*Aythya collaris*) and Lesser Scaup (*Aythya affinis*).
c) Pairs (P): male and female that are associated.
d) Flocked Drakes (FD): 2 to 4 males that are associated (recorded as "No(s)").
e) Groups: Five or more of the same species associated with one another.

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Estimates of spring breeding waterfowl populations are calculated using the following 2 formulae:

Formula 1: Indicated Breeding Birds (IBB) = (2 x P) + (2 x LD) + (2 x FD) + (1 x Grouped Birds), for the all species of waterfowl with the exception of Redhead, Lesser Scaup and Ruddy Duck.

Formula 2: Indicated Breeding Birds (IBB) = (2 x P) + (1 x LD) + (1 x FD) + (1 x Grouped Birds) + (1 x H), for Redhead, Lesser Scaup and Ruddy duck.

These formulae reflect differences among species in sex ratios present during the breeding season waterfowl surveys (Anonymous 1987).

Buffalo Lake Moraine

Estimates of waterfowl populations within the Buffalo Lake Moraine were based on data collected along 6 east-west road transects (Allen 1989). These road transects extended 200m north and south on either side of the center of the road. The total transect length in the study area is 159.3 km and the area within transects is 64.11 km^2. Of the 6 established transects, 4 were gravel roads, 1 transect is a secondary highway and 1 transect is a tertiary highway (Figure 2.2). Two breeding waterfowl surveys were conducted, with the initial waterfowl survey being completed during the first 2 weeks of May and the second survey conducted during the first week of June between 1989 – 2003. Surveys were completed every second year during this period. Using established methods, I augmented these data by completing an additional breeding waterfowl survey in 2004; combined with existing data, this resulted in a total of 9 surveys over the 16-year study period (1989 – 2004). In conjunction with the initial breeding waterfowl survey, wetlands were classified according to Stewart and Kantrud (1971).

Waterfowl breeding surveys in the Buffalo Lake Moraine were initiated at sunrise (approximately 5:00 am Mountain Daylight Savings Time (MDST)) and were concluded at approximately 12:00 noon (MDST) of each day, or when precipitation

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or wind speed limited visibility. Surveys were completed by driving along transects in an east to west direction to minimize glare from the sun. Observers stopped at each wetland along each transect and counted and recorded all waterfowl species present. Each wetland visit lasted approximately 2 – 15 minutes, depending upon the size and vegetation structure of individual wetlands.

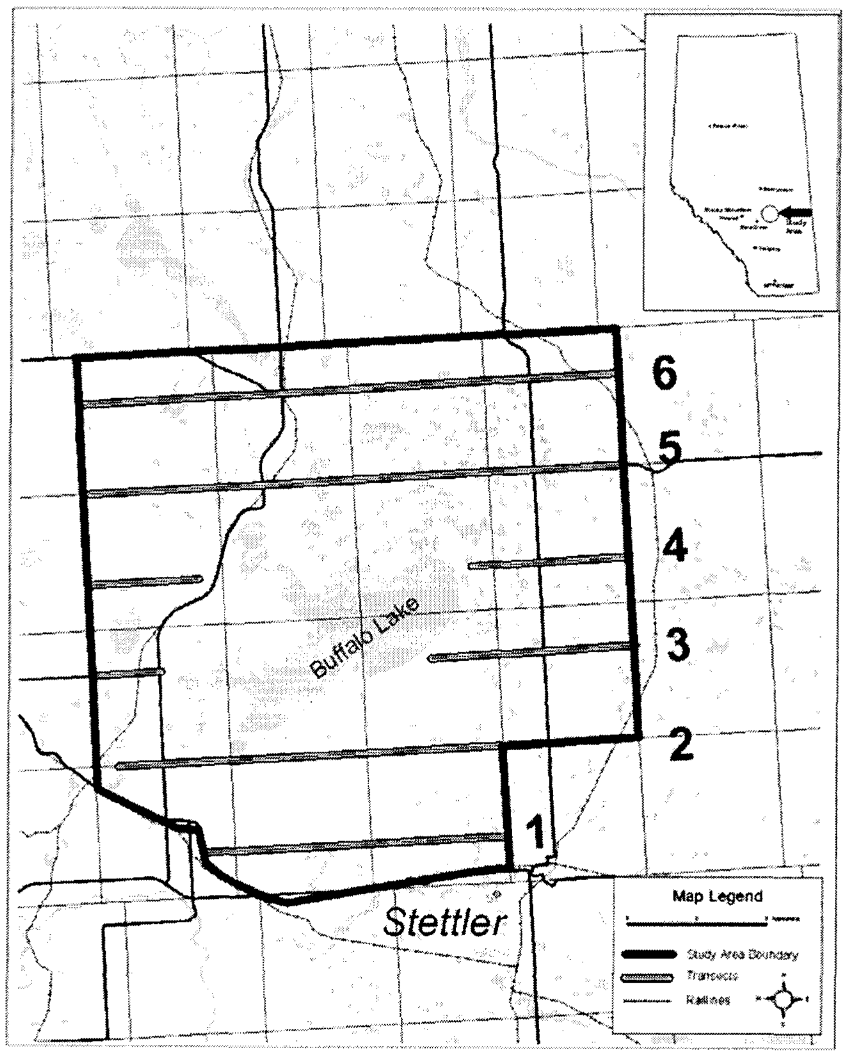

Figure 2.2: The Buffalo Lake Moraine study area located in east central Alberta. Study area transects were spatially separated north-south by a distance of 6.4 km.

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Species–specific Indicated Breeding Bird (IBB) estimates were calculated for each of the 2 breeding waterfowl surveys conducted in May and June of each survey year. These IBB estimates were then used to calculate spring breeding waterfowl population estimates for the Buffalo Lake Moraine study area. For each species, the breeding waterfowl survey, which contained the higher IBB, was used to estimate the density and total spring waterfowl population estimates. In addition to spring waterfowl population estimates, population estimates for select waterbird species were also calculated as a component of the Buffalo Lake Moraine study (Appendix 2.2).

Estimates for species-specific population densities were derived by dividing the calculated IBB for each species by the total transect area (64.11 km^2). The following formulae were used to calculate species specific population density estimates:

$$\text{Density (no. birds/ km}^2\text{)} = IBB_{species} / 64.11\ km^2$$

Total spring breeding waterfowl population estimates were then calculated by extrapolating the density within the transect area to the overall area of the Buffalo Lake study region (1,295 km^2). The following formula was used to calculate total spring breeding waterfowl population estimates for the Buffalo Lake Moraine:

$$\text{Total Spring Breeding Estimate} = IBB/64.11\ km^2 \times 1{,}295\ km^2$$

The distribution and abundance of select waterbird species were also recorded during the Buffalo Lake Moraine waterfowl study and included: American Coot, Horned Grebe (*Podiceps auritus)*, Red-necked Grebe (*Podiceps grisegena)* and Eared Grebe (*Podiceps nigricollos).* During each of the 2 breeding waterfowl surveys conducted in the Buffalo Lake Moraine described above, the total number of adults for each of these species was recorded. Following completion of both surveys, the greater number of adults observed on either of the 2 surveys was used to calculate an

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estimated density and total breeding population. The following formula was used to calculate an estimated density of select waterbird species:

$$\text{Density of Waterbirds (no. km/}^2\text{)} = \text{Total Adult Waterbird}_{\text{species}} / 64.11 \text{ km}^2$$

The following formula was then used to calculate the estimated total spring breeding population for select waterbird species:

$$\text{Total Spring Population Waterbird} = \text{Density (no./km}^2\text{)} \times 1{,}295 \text{ km}^2$$

Defining and classifying wetlands within the Buffalo Lake Moraine study area

All waterbodies included in the analysis and subsequent reporting will be referred to as wetlands. A wetland consisted of a minimum surface area of approximately $25 m^2$ of standing water. Densities of wetlands (number / km^2) were calculated by dividing the total number of wetlands counted each survey year within transects and then dividing that value by the transect study area (64.11 km^2). Wetlands that were either completely or partially within the transect area were classified and included in the calculation of wetland densities for the study area. Wetland classification was based on a basin's capacity to retain water throughout the spring and summer periods. Stewart and Kantrud (1971) used the following categories to classify wetlands: Dry (no surface water present in basin), Class I (ephemeral, surface water present for < 3 weeks), Class III (seasonal, surface water present for > 3 weeks and usually dry by July), Class IV (semi-permanent, surface water present until September-October in 7 out of 10 years) and Class V (permanent, surface water persisting throughout the year, except in periods of severe drought).

Statistical analyses

For statistical significance I employed a level of $P=0.05$ for all analyses. To describe the trends of regional and local waterfowl and waterbird breeding

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populations I completed the following 3 analyses. First, at a regional scale, I used linear regression to describe temporal changes between 1989 – 2004, in the density of breeding populations of waterfowl within Stratum 26. Second, I constructed linear regression models to describe population trends for the same species of waterfowl at a local scale, the Buffalo Lake Moraine for the same time period. Additionally, regression models were constructed for select waterbird species (listed above) within the Buffalo Lake Moraine. Third, I used linear regression to describe the relationship between species abundance and wetland density within the Buffalo Lake Moraine study area and Stratum 26 to describe the relationship between density of breeding waterfowl for individual species and wetland densities at both regional and local spatial scales. Additionally, I examined the relationship of local scale (i.e. Buffalo Lake Moraine) waterfowl breeding populations to the regional scale (i.e. Stratum 26) to describe the trends in estimated percentages of waterfowl in Stratum 26 that used the Buffalo Lake Moraine.

Where required, breeding population density data were log-transformed ($\log_{10}$) prior to analyses to fulfill assumptions of normality and homogeneity of variance. I used the Benjamini and Hochberg False Discovery Rate to adjust p-values, which were derived from multiple statistical testing (Benajamini and Hochberg 1995). The Benjamini and Hochberg False Discovery Rate was applied to analyses for waterfowl of the same foraging guild (i.e. dabblers and divers) and waterbirds. Analysis was completed for waterfowl species which were included in both the USFWS/CWS spring waterfowl surveys and the Buffalo Lake Moraine study: Mallard, Gadwall, American Wigeon *(Anas americana),* Green-wing Teal *(Anas crecca),* Blue-wing Teal, Northern Shoveler *(Anas clypeata),* Northern Pintail *(Anas acuta),* Redhead, Canvasback, Lesser Scaup, Common Goldeneye, Bufflehead, and Ruddy Duck.

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Use of nest boxes within the Buffalo Lake Moraine

Experimental design and nest box design

In 2004 and 2005, I conducted a 2-year manipulative experiment involving nest boxes to test the hypothesis that Common Goldeneye and Bufflehead abundance in the Buffalo Lake Moraine were limited by availability of suitable natural nesting sites. The suite of nest boxes used during the manipulation was initially deployed in the Buffalo Lake Moraine beginning in 1989. Due to female breeding philopatry of *Bucephala spp.,* I predicted that the number of Common Goldeneye and Bufflehead pairs settling on wetlands in the Buffalo Lake Moraine with either open or closed nest boxes would not differ significantly. If nesting sites limit reproductive output of Bufflehead and Common Goldeneye, I predicted that wetlands where Common Goldeneye and Bufflehead had access to next boxes would produce higher numbers of broods compared to wetlands where next boxes were closed.

Common Goldeneye nest boxes were rectangular boxes (an approximate height of 80 cm and width of 27 cm) constructed with 2.0 cm thick plywood. Nest box entrance holes were approximately 15 cm from the top of the box, allowing for an interior nesting depth of approximately 65 cm. Nest boxes had an oval entrance hole for Common Goldeneye with a diameter of 8 cm by 10 cm. Bufflehead nest boxes had an approximate length of 60 cm and width of 18 cm. The oval entrance hole for Bufflehead nest boxes had a diameter of 7 cm by 8 cm. Entrance holes were 15 cm from the top of the box, allowing for an interior nesting depth of approximately 45 cm. At installation, shaved wood chips were added to the boxes to provide approximately 15 cm of material on which Common Goldeneye and Bufflehead could establish nests. Although nest box design and dimensions have fluctuated somewhat throughout the study period I have presented the most common design.

Nest boxes were attached to large (diameter at breast height >20 cm) living trees near riparian areas, which included, trembling aspen (*Populus tremiouloides*), balsam poplar (*Populus balsamifera)* and paper birch (*Betula papyrifera*). Stucco

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wire was wrapped around and stapled to the base of trees that contained nest boxes to prevent tree cutting by beaver (*Castor canadensis).* Nest boxes were attached to trees so that the entrance hole was minimally 1.3 m from the base of the tree to inhibit potential mammalian predators. In the majority of cases, 1 or 2 nest boxes for each species were installed at individual wetlands with suitable wooded riparian areas and water levels. Often, 1 Common Goldeneye and 1 Bufflehead nest box were installed on the same tree, with the Bufflehead box being installed above the Common Goldeneye box. On wetlands with more than 1 box for the same species, a distance greater than 75 m separated boxes.

Using a single-stage cluster sampling design (Hayek and Buzas 1997), I systematically divided the 6 established Buffalo Lake Moraine transects into alternating clusters of wetlands where existing nest boxes were either open or closed for occupancy by Common Goldeneye and Bufflehead (Figure 2.3). When using a single-stage cluster sampling design, the following conditions must be met: a) individual clusters must not overlap and, b) each organism being counted can be in only 1 cluster (Hayek and Buzas 1997). Clusters of nest boxes, immediately adjacent to wetlands, were alternated by cluster type (i.e., nest boxes open or closed) along transects and were spatially separated (> 800 m) (Figure 2.3; Appendix 2.3, Appendix 2.4). This approach resulted in a systematic sequence of clusters of open and closed boxes along each of the 6 transects and was designed to randomize any potential effects of an east-west or north-south gradients in nest box occupancy. While the above protocol was used in the majority of cases, the existing spacing of Bufflehead nest boxes along transects, resulted in one case where 2 open clusters could not be separated by an alternating closed cluster. In this situation, a distance of 6 km separated the 2 open clusters.

An individual cluster consisted of 6 to 34, class III – V wetlands and varied in length from 0.73 km to 17.63 km. Individual clusters were located along the study transects, and extended 200 m north and south from the middle of each transect. Clusters were separated spatially by a minimum of 800 m east and west along the

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clusters, and individual transects were separated by a minimum of 6 km north and south. A study in the Canadian Precambrian Shield, near Sudbury, Ontario, showed that within an individual breeding season, Common Goldeneye broods typically restrict their movements to rearing lakes that are relatively close to nest sites (i.e. < 1 km) (Wayland and McNicol 1994). Although the Wayland and McNicol (1994) study was conducted in a different geographical location, I could find no studies regarding *Bucephala* brood movement in the aspen parkland. Thus, to reduce the potential confounding effects of Common Goldeneye and Bufflehead moving between clusters of different types, I ensured that a minimum linear distance of 800 m separated clusters.

During the manipulation, nest boxes that were closed (i.e., not accessible for occupancy by Common Goldeneye and Bufflehead) had the entry hole covered by a 6 cm x 6 cm piece of plywood. To reduce the conspicuousness of the nest boxes, nest boxes that were closed were also covered with commercially available burlap fabric. During the nest box manipulation (2004 – 2005), occupancy of open nest boxes was based on visual examination of the nest boxes during the spring breeding season and with the presence of unhatched eggs. Nest box occupancy (1989 – 2003) was based on visual examination of the nest boxes during the breeding season or the following winter when the presence of unhatched eggs, egg shells or yolk sacs indicated that the nest had been occupied. Boxes were first deployed to provide nesting sites in the Buffalo Lake Moraine in spring 1989 (i.e., available for the 1989 breeding season) for Common Goldeneye and in spring 1991 (i.e., available for the 1991 breeding season) for Bufflehead (Potter 2004). As a component of the ongoing Alberta Conservation Association and Ducks Unlimited Canada nest box program, boxes were monitored annually between 1989 – 1995 and subsequently monitored in 1999, 2001, 2002 and 2003 (Appendix 2.5) (Potter 2004). As a component of the nest box manipulation experiment, 51 and 66 nest boxes for Common Goldeneye and 33 and 38 nest boxes for Bufflehead were monitored in 2004 and 2005, respectively.

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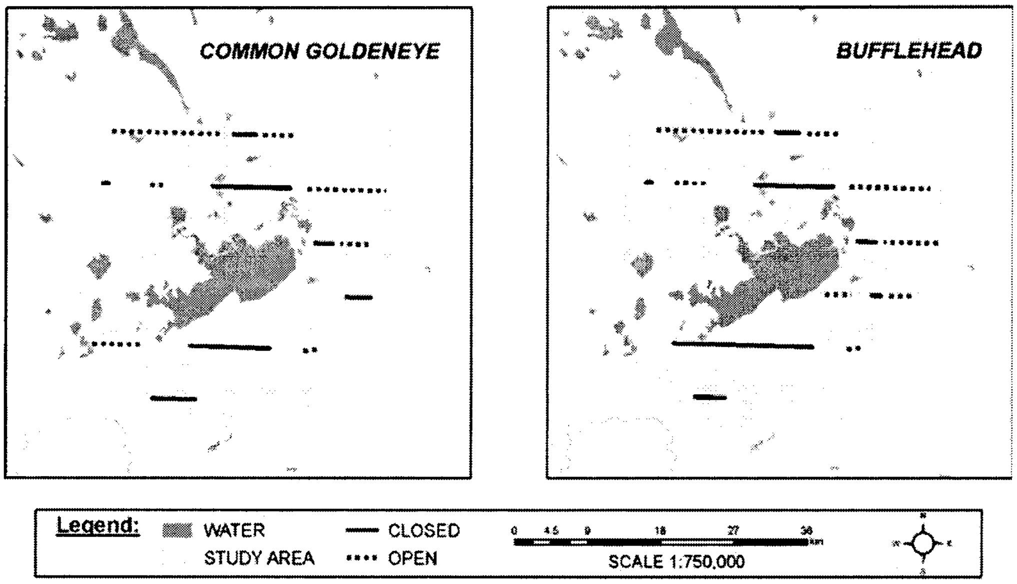

Figure 2.3: Location of clusters of waterbodies where existing nest boxes were open or closed to occupancy by Common Goldeneye and Bufflehead in the Buffalo Lake Moraine in central Alberta. Clusters of waterbodies were separated by at least 800 m to minimize the potential movements of birds from waterbodies where nest boxes were open from areas where boxes were closed.

Broods surveys for Common Goldeneye and Bufflehead began the first week of June. Wetlands were surveyed every 2 to 4 days between 1 June and 15 July 2004 to encompass the known mean hatching dates for Common Goldeneye (June 17) and Bufflehead (June 26) in the Buffalo Lake Moraine (Murphy *et. al.* 2004). An additional brood survey was conducted the first week of August to ensure any late-hatching broods were observed. Brood surveys were conducted along the study area transects commencing at sunrise (approximately 5:00 am Mountain Daylight Savings Time (MDST)) and were concluded at approximately 12:00 noon of each day, or if precipitation or wind speed limited visibility. Surveys were conducted by driving along transects in an east to west direction to minimize glare from the sun. Observers stopped at each wetland and used binoculars to survey its perimeter and surface water for the presence of *Bucephala spp.* broods. If the observers could not adequately see the entire wetland from a single vantage point, they walked the

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perimeter to ensure any previously unseen *Bucephala spp.* broods were flushed into open water and identified. Once a Common Goldeneye or Bufflehead brood was observed, the young were counted and aged according to plumage development as described by Gollup and Marshall (1954). Once a brood was encountered and aged on a particular wetland, it was monitored by observers to ensure that it was not counted again on a nearby wetland.

Comparison of habitat characteristics between clusters

I used a Geographic Information System (GIS) and completed queries to compare habitat attributes for the area within each open and closed cluster. The area of each cluster was delineated by including the area <200m north and south of the centre line from each transect, along the entire length of individual transects. Habitat attributes were obtained from the Native Parkland Vegetation Inventory (Bjorge 2003) and included: wetland surface area (hectares), shoreline length (kilometers), area in deciduous forest (hectares) and perimeter of deciduous forest (kilometers). Habitat variables were only measured for the area within each individual cluster. I measured and compared these attributes to determine whether expected differences in the number of broods and brood size between cluster type (i.e. wetlands that contained open versus closed nest boxes) could be explained by differences between the characteristics of terrestrial and wetland habitats associated with clusters rather than to the experimental manipulation itself. In addition to the above-mentioned habitat variables, I compared the number of class III – V wetlands (Stewart and Kantrud 1971) in each cluster as determined during the initial spring waterfowl survey. I chose to compare Class III-V wetlands due to permanency and likelihood of retaining water throughout the brood rearing season. A summary of habitat variables for individual clusters can be found in Appendix 2.6)

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Statistical analyses

Using the single stage cluster design described, I established a total of 15 clusters of wetlands along the 6 transects where existing nest boxes were open or closed to occupancy by Common Goldeneye (7 open and 7 closed) and Bufflehead (8 open and 7 closed), in 2004. For statistical analyses, I considered an individual cluster to be the unit of replication. As a result, I tested the hypotheses that the mean number of pairs (i.e. number per cluster), mean number of broods (i.e. number of broods per cluster) and mean brood size (i.e. number of ducklings per brood for each cluster) were not affected by cluster type (i.e. open versus closed nest boxes) using a t-test. These analyses, conducted separately for Common Goldeneye and Bufflehead, were completed after creating an overall average of each response variable within each cluster. Thus, t-tests were based on 7 replicates for Common Goldeneye and 8 replicates for Bufflehead.

I used a Wilcoxon rank-sum test to determine whether habitat characteristics of wetlands and their respective wooded deciduous uplands differed between the two cluster types. Lastly, I documented temporal variation in the occupancy of nest boxes in the Buffalo Lake Moraine qualitatively by comparing occupancy of nest boxes by Common Goldeneye and Bufflehead nest boxes over time. In the Buffalo Lake Moraine, Common Goldeneye nest boxes were installed beginning in 1989 and Bufflehead nest boxes were installed in 1991. Nest boxes were monitored annually for occupancy by Common Goldeneye and Bufflehead to ensure that they continued to provide nesting sites (Appendix 2.6). To be considered occupied, a nest box had to contain evidence of breeding from the previous breeding season. Using a 2 x 2 contingency table and a chi-square test, I compared occupancy rates of Common Goldeneye nest boxes in 2005, which were either open or closed in 2004 (Zar 1999). By closing nest boxes in 2004, I eliminated these suitable nest sites for nesting that year. *Bucephala spp,* are highly philopatric and will return to nest sites which were used in previous breeding seasons (Dow and Fredga, 1983, Dow and Fredga 1985, Savard and Eadie 1989 and Gautier 1990). By examining nest box occupancy in 2005, I assessed re-occupancy rates. High re-occupancy rates would provide further

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evidence that natural sites were limited. During nest box occupancy checks in 2004 and 2005, I determined clutch sizes for Common Goldeneye nests. Nest boxes were checked during times when hens were likely to be taking incubation breaks (1000 – 1600 hours), and during the later stages of incubation to reduce the likelihood of nest abandonment (Gautier 1993, Zicus *et al.* 1995, Eadie *et al.* 1995).

RESULTS

Empirical model explaining variance in waterfowl and waterbird species

Density of waterfowl and waterbird species versus time

The density of waterfowl species measured at the larger spatial scale of Stratum 26 did not vary with year (Table 2.1). Linear regression models (13 of the 13 species models) revealed that waterfowl density was stable ($P > 0.05$) throughout the 16-year study period, including densities of Common Goldeneye and Bufflehead. Additionally, when data from all species were combined, regression models showed that the densities of diving and dabbling duck feeding-guilds and all ducks combined did not vary with year. Only the density of American Coot declined significantly ($P < 0.05$) across the study period. Linear regression models for Gadwall, Blue-winged Teal, Northern Pintail and Lesser Scaup all exhibited strong relationships ($r^2 > 0.30$) between density and year. With the exception of Canvasback, Common Goldeneye and Bufflehead, all linear regression models were negatively related with year.

Densities of waterfowl species in the Buffalo Lake Moraine (i.e., at the local scale) were stable (13 of the 13 species) over the 16-year study period extending from 1989 to 2004 (Table 2.2). Although population trends were not statistically significant, the densities of the majority of waterfowl species were negatively related to year. Specifically, densities of 7 waterfowl species demonstrated strong ($r^2 > 0.30$) negative relationships with year; Mallard, Blue-winged Teal, Northern Pintail, Canvasback and Lesser Scaup all were negatively related to year with only 2 species, Common Goldeneye and Bufflehead demonstrating positive population trends across the study period (Table 2.2). When data from all species were combined, regression

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models showed that the densities of both dabbling and diving ducks were stable ($P>0.05$), however, they were also negatively ($r^2>0.30$) related to year (Table 2.2). Although not statistically significant, of the 4 waterbird species surveyed in the Buffalo Lake Moraine, 3 species, American Coot, Horned Grebe and Red-necked Grebe were negatively associated with year; Red-necked Grebe ($P<0.01$) densities declined significantly throughout the study period (Table 2.2). In contrast to regression models derived from the regional spatial scale of Stratum 26, densities of Common Goldeneye (Figure 2.4) and Bufflehead (Figure 2.5) at the smaller spatial scale were more strongly related to sampling year (Table 2.2). The only waterfowl or waterbird species demonstrating positive population growth at the spatial scale of the Buffalo Lake Moraine, were Common Goldeneye and Bufflehead.

Table 2.1: Summary of linear regression models describing relations between the density (Log_{10} Number/km^2) of select waterfowl species and the density (Number/km^2) of select waterbird species and sample year (1989 – 2004) in Stratum 26 in central Alberta. Degrees of freedom for all analyses = 1,7. Statistically significant ($P<0.05$) regression models are highlighted in bold and regression models with $r^2>0.30$ are highlighted in italics. Censuses were completed in 1989, 1991, 1993, 1995, 1997, 1999, 2001, 2003 and 2004. Adjusted p-values reflect application of Benjamini and Hochberg False Discovery Rate for multiple statistical testing.

Species/Group	**Regression Model**	**F**	**R^2**	**P**	**Adjusted P**
Mallard	Log_{10} Y = 10.99 – 0.005 (year)	0.59	0.08	0.47	0.66
Gadwall	*Log_{10} Y = 28.22 – 0.014 (year)*	*3.50*	*0.33*	*0.11*	*0.26*
American Wigeon	Log_{10} Y = 12.78 – 0.006 (year)	0.76	0.10	0.41	0.71
Green-winged Teal	Log_{10} Y = 14.65 – 0.007 (year)	0.29	0.04	0.61	0.71
Blue-winged Teal	*Log_{10} Y = 33.67 – 0.017 (year)*	*6.52*	*0.48*	*0.04*	*0.26*
Northern Shoveler	Log_{10} Y = 4.24 – 0.002 (year)	0.10	0.02	0.76	0.76
Northern Pintail	*Log_{10} Y = 49.52 – 0.025 (year)*	*4.60*	*0.39*	*0.07*	*0.24*
All dabblers	Log_{10} Y = 20.32 – 0.010 (year)	2.79	0.28	0.14	0.69
Redhead	Log_{10} Y = 39.23 – 0.020 (year)	1.72	0.20	0.23	0.92
Canvasback	Log_{10} Y = -2.00 + 0.001 (year)	0.01	<0.01	0.92	0.92
Lesser Scaup	*Log_{10} Y = 49.80 – 0.025 (year)*	*3.68*	*0.34*	*0.10*	*0.90*
Common Goldeneye	Log_{10} Y = -25.84 + 0.012 (year)	0.23	0.03	0.64	0.90
Bufflehead	Log_{10} Y = -13.39 + 0.007 (year)	0.65	0.08	0.49	0.98
Ruddy Duck	Log_{10} Y= 9.01 – 0.005 (year)	0.10	0.02	0.76	0.91
All divers	Log_{10} Y= 22.14 – 0.011 (year)	2.24	0.24	0.18	0.18
All ducks	Log_{10} Y= 20.86 – 0.010 (year)	2.84	0.29	0.14	0.14
American Coot	**Y =203.85 – 0.101 (year)**	**12.58**	**0.64**	**0.01**	**0.01**

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Table 2.2: Summary of linear regression models describing relations between the density (Log_{10} Number/km^2) of select waterfowl species and the density (Number/km^2) of select waterbird species and sample year (1989 – 2004) in the Buffalo Lake Moraine in central Alberta. Degrees of freedom for all analyses = 1,7. Statistically significant ($P<0.05$) regression models are highlighted in bold and regression models with $r^2 > 0.30$ are highlighted in italics. Censuses were completed in 1989, 1991, 1993, 1995, 1997, 1999, 2001, 2003 and 2004. Adjusted p-values reflect application of Benjamini and Hochberg False Discovery Rate for multiple statistical testing.

Species/Group	Regression Model	F	R^2	P	Adjusted P
Mallard	*Log_{10} Y = 42.21 – 0.021 (year)*	*6.15*	*0.47*	*0.04*	*0.09*
Gadwall	Log_{10} Y = 13.51 –0.006 (year)	0.64	0.08	0.45	0.63
American Wigeon	Log_{10} Y = 43.10 – 0.021 (year)	1.92	0.22	0.21	0.37
Green-winged Teal	Log_{10} Y = 3.90 – 0.002 (year)	0.01	0.01	0.92	0.92
Blue-winged Teal	*Log_{10} Y = 54.50 – 0.027 (year)*	*11.24*	*0.62*	*0.01*	*0.08*
Northern Shoveler	Log_{10} Y = 21.77 – 0.010 (year)	0.59	0.08	0.47	0.55
Northern Pintail	*Log_{10} Y = 79.50 – 0.040 (year)*	*7.67*	*0.52*	*0.03*	*0.10*
All dabblers	*Log_{10} Y = 36.98 – 0.018 (year)*	*4.29*	*0.38*	*0.08*	*0.08*
Redhead	Log_{10} Y = 35.31 – 0.017 (year)	1.92	0.22	0.21	0.25
Canvasback	*Log_{10} Y = 92.86 – 0.046 (year)*	*7.58*	*0.52*	*0.03*	*0.08*
Lesser Scaup	*Log_{10} Y = 69.53 – 0.034 (year)*	*4.81*	*0.41*	*0.06*	*0.10*
Common Goldeneye	*Log_{10} Y = -86.35 +0.043 (year)*	*11.52*	*0.62*	*0.01*	*0.07*
Bufflehead	*Log_{10} Y = -29.67 + 0.015 (year)*	*5.33*	*0.43*	*0.05*	*0.11*
Ruddy Duck	Log_{10} Y = 64.67 – 0.032 (year)	1.40	0.17	0.28	0.28
All divers	Log_{10} Y = 32.34 – 0.015 (year)	1.79	0.20	0.22	0.22
All Ducks	*Log_{10} Y = 34.28 – 0.016 (year)*	*4.19*	*0.38*	*0.08*	*0.08*
American Coot	Y = 714.05 – 0.353 (year)	1.08	0.13	0.33	0.33
Horned Grebe	*Y = 186.11 – 0.092 (year)*	*3.77*	*0.35*	*0.09*	*0.14*
Red-necked Grebe	**Y = 62.32 – 0.031 (year)**	**13.34**	**0.66**	**<0.01**	**0.02**
Eared Grebe	Y =- 16.01 + 0.008 (year)	1.08	0.13	0.33	0.33

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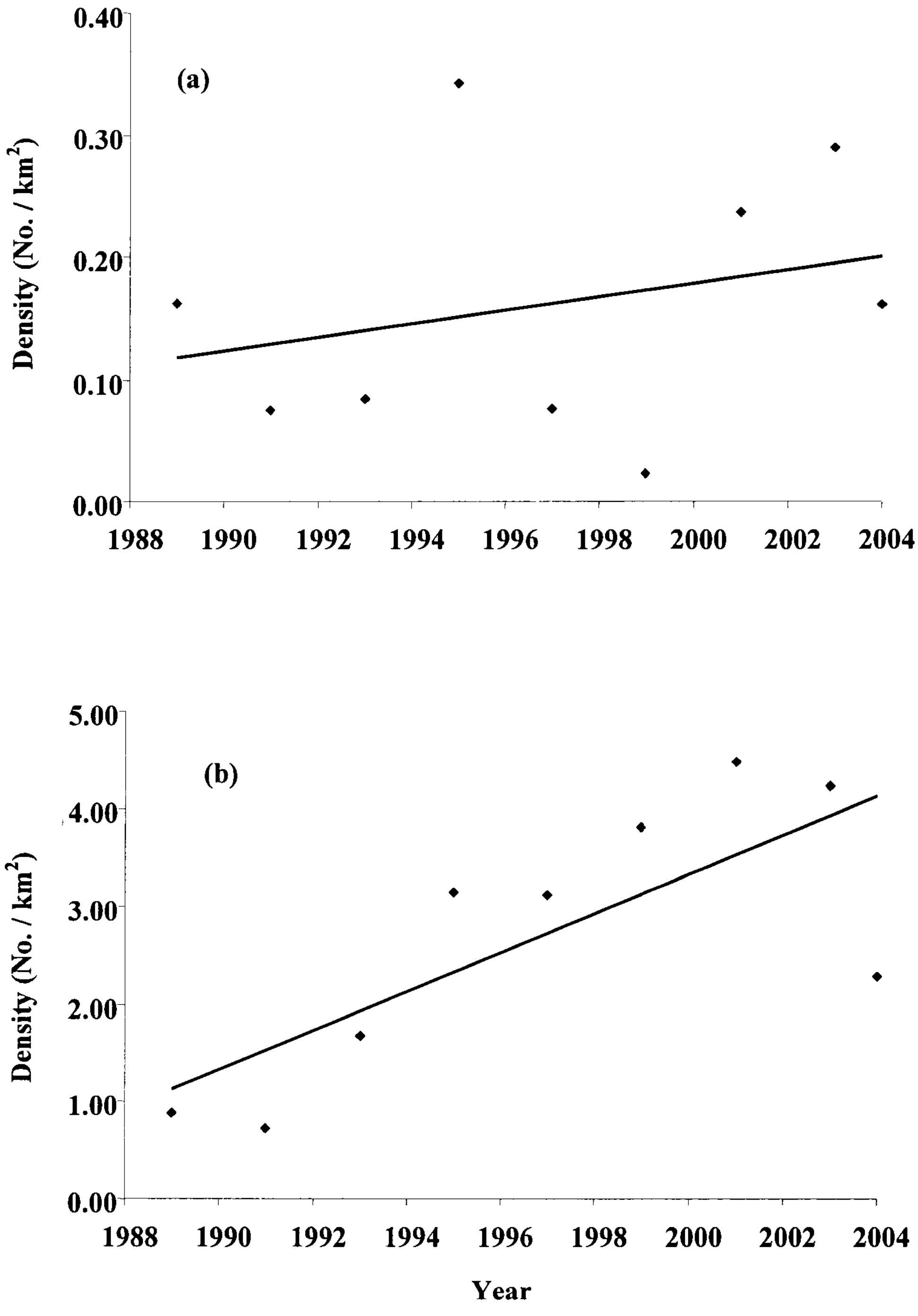

Figure 2.4: Comparison of linear regression models relating the temporal relationship of spring breeding population (No. / km^2) of Common Goldeneye versus year in (a) Stratum 26 and (b) in the Buffalo Lake Moraine in central Alberta, 1989 – 2004.

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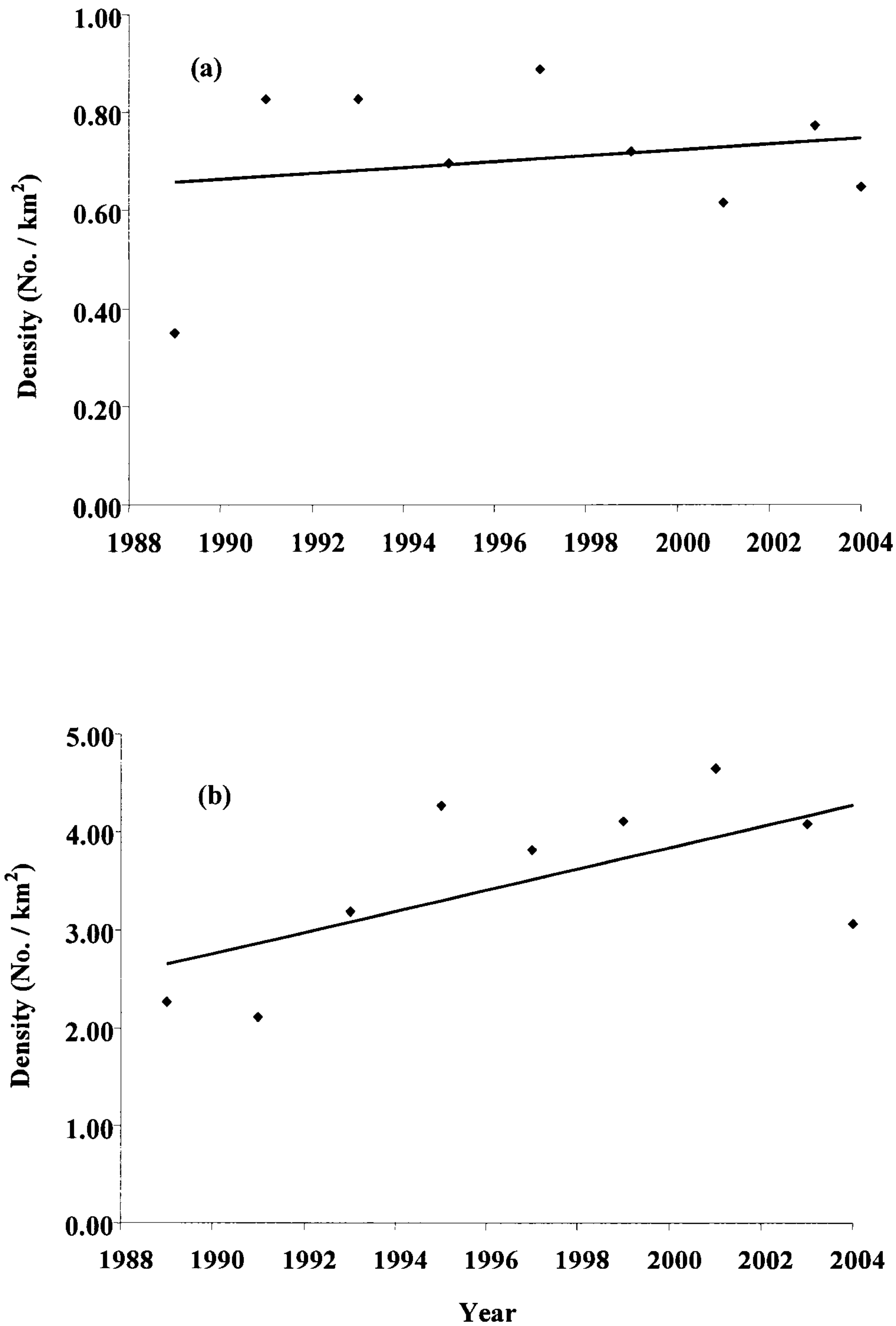

Figure 2.5: Comparison of linear regression models relating the temporal relationship of spring breeding population (No. / km^2) of Bufflehead versus year in (a) Stratum 26 and (b) the Buffalo Lake Moraine in central Alberta, 1989 – 2004.

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Density of waterfowl and waterbird species versus wetland density

At a regional spatial scale, linear regression models revealed there were no statistically significant relationships between dabbling duck species and wetland densities within Stratum 26 (Table 2.3). However, both Green-winged Teal and Northern Pintail demonstrated strong (r^2>0.30) correlations between species and wetland density. Linear regression models revealed that diving ducks increased with increasing wetland density within Stratum 26 (4 of 6 species) (Table 2.3). Regional densities of Redhead and Canvasback were significantly and positively related to wetland density during this study period; furthermore, densities of Lesser Scaup and Bufflehead exhibited a strong correlation (r^2>0.30) with wetland density. The correlation between divers and wetland densities exhibited stronger relationships compared to the correlation of annual wetland densities and dabblers at the regional scale (Table 2.3).

Table 2.3: Summary of linear regression models describing relationships between estimated spring breeding populations (Log_{10} no./km^2_{log}) for select waterfowl species and breeding population (no./km^2) for select waterbird species and wetland density (no. / km^2) in Stratum 26 in central Alberta. Degrees of freedom for all analysis = 1,7. Statistically significant (P<0.05) regression models are highlighted in bold and regression models with r^2 >0.30 are highlighted in italics. Adjusted p-values reflect application of Benjamini and Hochberg False Discovery Rate for multiple statistical testing.

Species	Regression Model	F	R^2	P	Adjusted P
Mallard	Log_{10} Y = 0.55 +0.030 (wetland)	1.71	0.20	0.23	0.40
Gadwall	Log_{10} Y = 0.22 + 0.018 (wetland)	0.31	0.04	0.60	0.70
American Wigeon	Log_{10} Y = -0.216 + 0.035 (wetland)	1.97	0.20	0.20	0.46
Green-winged Teal	*Log_{10} Y = -0.30 + 0.090 (wetland)*	*5.75*	*0.45*	*0.05*	*0.17*
Blue-winged Teal	Log_{10} Y = 0.48 – 0.008 (wetland)	0.06	0.01	0.82	0.82
Northern Shoveler	Log_{10} Y = 1.46 + 0.104 (wetland)	1.13	0.14	0.32	0.45
Northern Pintail	*Log_{10} Y = -0.69 + 0.11 (wetland)*	*9.98*	*0.59*	*0.02*	*0.11*
All dabblers	Log_{10} Y = 1.02 + 0.032 (wetland)	2.21	0.24	0.18	0.18
Redhead	**Log_{10} Y = -0.66 + 0.130 (wetland)**	**12.69**	**0.64**	**0.01**	**0.04**
Canvasback	**Log_{10} Y = -0.64 + 0.064 (wetland)**	**15.42**	**0.69**	**<0.010.04**	
Lesser Scaup	*Log_{10} Y = -0.18 + 0.092 (wetland)*	*3.77*	*0.35*	*0.09*	*0.14*
Common Goldeneye	Log_{10} Y = -0.40 – 0.119 (wetland)	1.95	0.22	0.21	0.25
Bufflehead	*Log_{10} Y = -0.38 + 0.051 (wetland)*	*4.06*	*0.37*	*0.08*	*0.16*
Ruddy Duck	Log_{10} Y = -0.41 + 0.035 (wetland)	0.47	0.06	0.52	0.52
All divers	**Log_{10} Y = 0.38 + 0.067 (wetland)**	**16.58**	**0.70**	**<0.01**	**<0.01**
All ducks	*Log_{10} Y = 1.11 + 0.041 (wetland)*	*4.13*	*0.37*	*0.08*	*0.08*
American Coot	Y= 1.09 + 0.148 (wetland)	0.80	0.10	0.40	0.40

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Within the Buffalo Lake Moraine, there was no correlation between the densities of dabbling ducks and the annual densities of wetlands (Table 2.4). Densities for 4 of the 7 species of dabblers were positively correlated to wetland density, however, none of the relationships were significant. Of all the dabbling duck species, only Mallard indicated a strong correlation ($r^2>0.30$) with wetland density within the Buffalo Lake Moraine. Regression models for diving ducks revealed that the densities of most species were positively correlated with wetland densities with the relationship being significant for Redhead, Canvasback, Lesser Scaup and Ruddy Duck (Table 2.4). Of the diving duck species, only Common Goldeneye and Bufflehead densities were not significantly correlated to wetland densities at the local spatial scale. Additionally, there was a significant relationship between densities of all diving ducks combined and annual wetland density. Linear regression models also revealed that densities of waterbird species within the Buffalo Lake Moraine were strongly correlated ($r^2>0.30$) with wetland densities, Eared Grebe was the only exception (Table 2.4).

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Table 2.4: Summary of linear regression models describing relationships between estimated spring breeding populations (Log $_{10}$ no. /km ^{2}) for select waterfowl species and breeding populations (no. /km ^{2}) for select waterbird populations and wetland density (no./km ^{2}) in the Buffalo Lake Moraine in central Alberta. Degrees of freedom for all analysis = 1,7. Statistically significant (P<0.05) regression models are highlighted in bold and regression models with r^2 >0.30 are highlighted in italics. Adjusted p-values reflect application of Benjamini and Hochberg False Discovery Rate for multiple statistical testing.

Species	Regression Model	F	R^2	P	Adjusted P
Mallard	*Log_{10} Y = 0.92 +0.019 (wetland)*	*3.09*	*0.31*	*0.12*	*0.84*
Gadwall	Log_{10} Y = 1.09 – 0.002 (wetland)	0.04	<0.01	0.84	>1.00
American Wigeon	Log_{10} Y = 0.42 + 0.002 (wetland)	0.01	0.01	0.94	0.94
Green-winged Teal	Log_{10} Y = 0.58 – 0.002 (wetland)	0.03	0.01	0.91	>1.00
Blue-winged Teal	Log_{10} Y = 1.01 + 0.016 (wetland)	1.35	0.16	0.28	0.98
Northern Shoveler	Log_{10} Y = 1.02 – 0.013 (wetland)	0.74	0.10	0.42	0.98
Northern Pintail	Log_{10} Y = 0.10 + 0.002 (wetland)	0.01	0.01	0.92	>1.00
All dabblers	Log_{10} Y = 1.68 + 0.007 (wetland)	0.38	0.05	0.59	0.59
Redhead	**Log_{10} Y = 0.26 + 0.032 (wetland)**	**9.34**	**0.57**	**0.02**	**0.04**
Canvasback	**Log_{10} Y = -0.71 +0.058 (wetland)**	**11.23**	**0.62**	**0.01**	**0.04**
Lesser Scaup	**Log_{10} Y = 0.28 +0.045 (wetland)**	**8.40**	**0.55**	**0.02**	**0.04**
Common Goldeneye	Log_{10} Y = 0.29 + 0.004 (wetland)	0.03	0.01	0.86	0.86
Bufflehead	Log_{10} Y = 0.46 + 0.004 (wetland)	0.20	0.03	0.67	0.78
Ruddy Duck	**Log_{10} Y = -0.88 +0.080 (wetland)**	**27.36**	**0.80**	**<0.01**	**<0.01**
All divers	**Log_{10} Y = 0.95 + 0.031 (wetland)**	**12.34**	**0.64**	**0.01**	**0.01**
All ducks	Log_{10} Y = 1.74 + 0.014 (wetland)	1.85	0.21	0.22	0.22
American Coot	*Y = - 4.79 + 0.837 (wetland)*	*9.40*	*0.57*	*0.02*	*0.07*
Horned Grebe	*Y = 0.38 + 0.109 (wetland)*	*4.20*	*0.38*	*0.08*	*0.11*
Red-necked Grebe	*Y = -0.08 + 0.031 (wetland)*	*6.85*	*0.50*	*0.04*	*0.07*
Eared Grebe	Y = 0.41 – 0.012 (wetland)	1.83	0.21	0.22	0.22

Relative abundance of waterfowl in the Buffalo Lake Moraine

I calculated average percentage of the total estimated individuals in Stratum 26 that were settling in the Buffalo Lake Moraine from 1989 – 2004 for 13 species of waterfowl. These analyses allowed me to assess the relative importance of the Buffalo Lake Moraine for each species in relation to the entire population in Stratum 26. Assuming that the Buffalo Lake Moraine is representative of the entire Stratum 26, waterfowl should be evenly distributed at the regional scale. Approximately 1.44% of the regional land base (Stratum 26) is found within the study area (Buffalo Lake Moraine), consequently, this percentage of waterfowl should utilize the Buffalo Lake Moraine for breeding. Throughout the study period, the relative abundance of

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all waterfowl species occurred at a level exceeding the expected 1.44%, as the Buffalo Lake Moraine contributed 3 – 5% of breeding birds for most species (Figure 2.6). By far, the greatest dependence of a single species on the Buffalo Lake Moraine, within Stratum 26 was displayed by Common Goldeneye (11.82%) (Figure 2.6). In contrast, Bufflehead (3.64%) ranked fifth when I compared percentage of breeding individuals at the local scale compared to the regional scale and did not differ markedly from a number of other diving duck species.

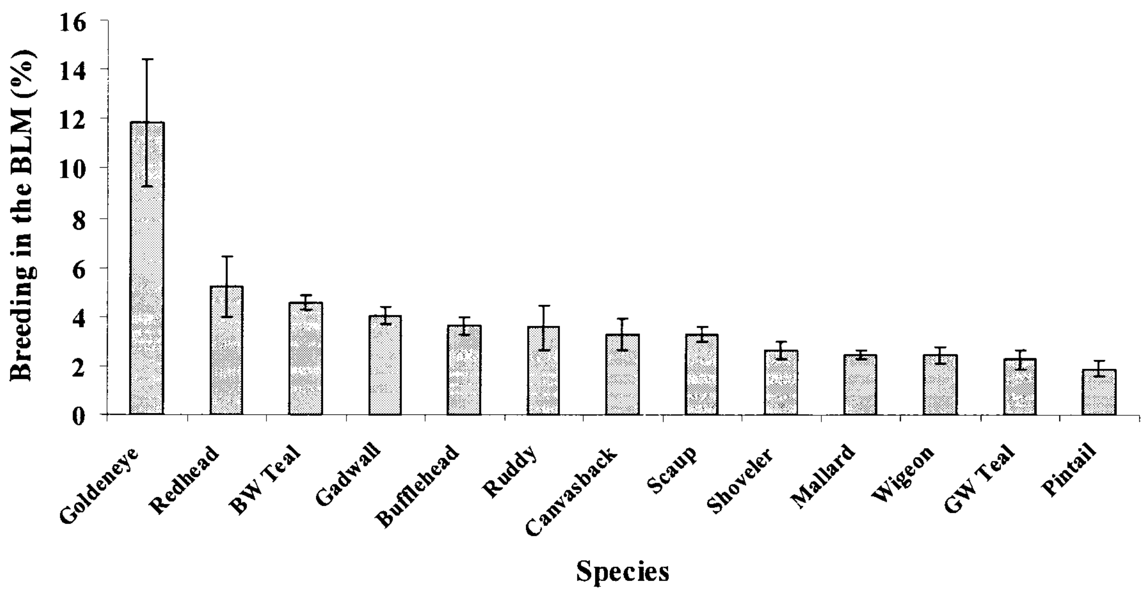

Figure 2.6: Percentage of total spring waterfowl breeding population in Stratum 26 that occurred in the Buffalo Lake Moraine. Values represent the mean percentage of breeding waterfowl in the Buffalo Lake Moraine; 1989 – 2004.

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Temporal variation in the occupancy of nest boxes

Occupancy of available nest boxes by Common Goldeneye increased gradually from about 10% in 1989 to about 85% percent in 1993. Since that time, nest box occupancy has remained relatively constant, ranging from 82 to 96% (Figure 2.7). In 2004, approximately half of the existing nest boxes located along transects in the Buffalo Lake Moraine study area were closed, as part of the nest box manipulation experiment. Of the remaining usable boxes in 2004 (N= 51 nest boxes) 92% were occupied by nesting Common Goldeneye. Following a similar pattern, Bufflehead nest box occupancy gradually increased from approximately 7.5% in 1991 to 31.3% in 1994. Since 1994, Bufflehead nest box occupancy has remained between 30% and 59%. Of the remaining usable boxes in 2004 (N= 33 nest boxes) 30.30% were occupied by nesting Bufflehead. The number of Common Goldeneye and Bufflehead nest boxes monitored annually for occupancy each year can be found in Appendix 2.5.

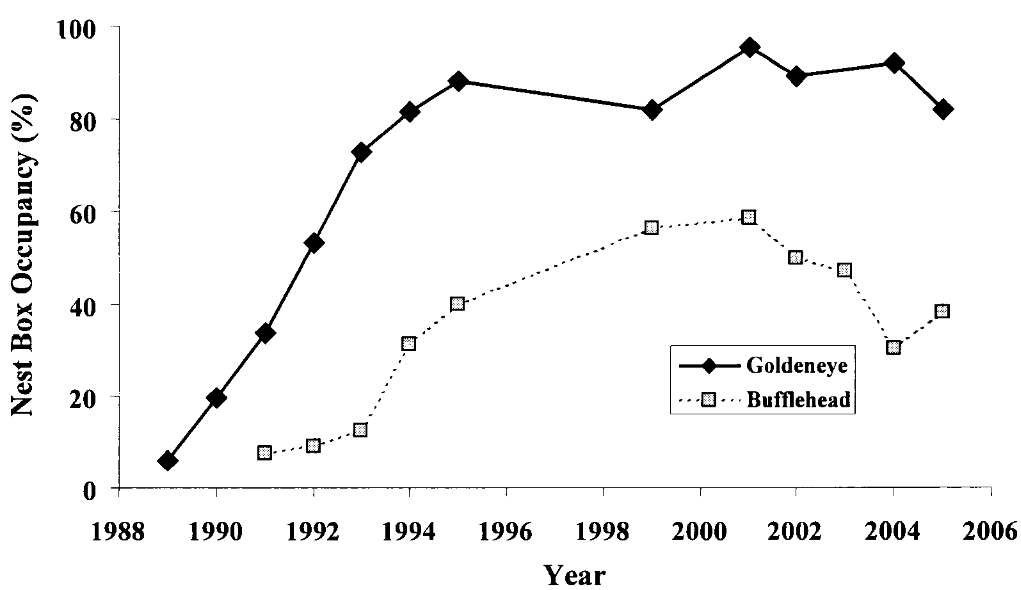

Figure 2.7: Temporal variation in the occupancy of nest boxes by Common Goldeneye and Bufflehead in the Buffalo Lake Moraine; 1989 – 2005.

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Nest box manipulation

Comparisons of density of Common Goldeneye and Bufflehead pairs, density of broods and brood size

Responses by Common Goldeneye and Bufflehead to nest box closure were species-specific (Figure 2.8). Mean number of pairs of Common Goldeneye did not differ significantly (P=0.87) between clusters of wetlands where nest boxes were available for occupancy compared to clusters where nest boxes were closed (Figure 2.8). In contrast, the mean number of Common Goldeneye broods and brood size were significantly (both P=<0.001) higher in clusters where nest boxes were available compared to those where nest boxes were closed. Common Goldeneye broods were detected in 7 out of 7 clusters where nest boxes were available for use, whereas, in clusters where nest boxes were closed, broods were detected in only 2 of the 7 clusters. This result suggests that availability of nest boxes limited reproductive output by Common Goldeneye hens, but did not affect the use of wetlands by Common Goldeneye pairs.

In contrast to Common Goldeneye, the mean number of pairs (P= 0.75) and the mean number of broods (P = 0.14) of Bufflehead did not differ significantly between clusters with open versus closed boxes, although the number of broods tended to be lower in the closed clusters. However, the mean brood size (P=0.07) was larger for clusters with open versus closed nest boxes for Bufflehead. Additionally, 7 out of the 8 clusters, which had open nest boxes produced at least 1 brood, whereas only 3 out of 7 clusters with closed nest boxes produced Bufflehead broods. The number of pairs, broods and brood sizes for individual clusters as well as the means and standard errors for open and closed clusters can be found in Appendix 2.7.

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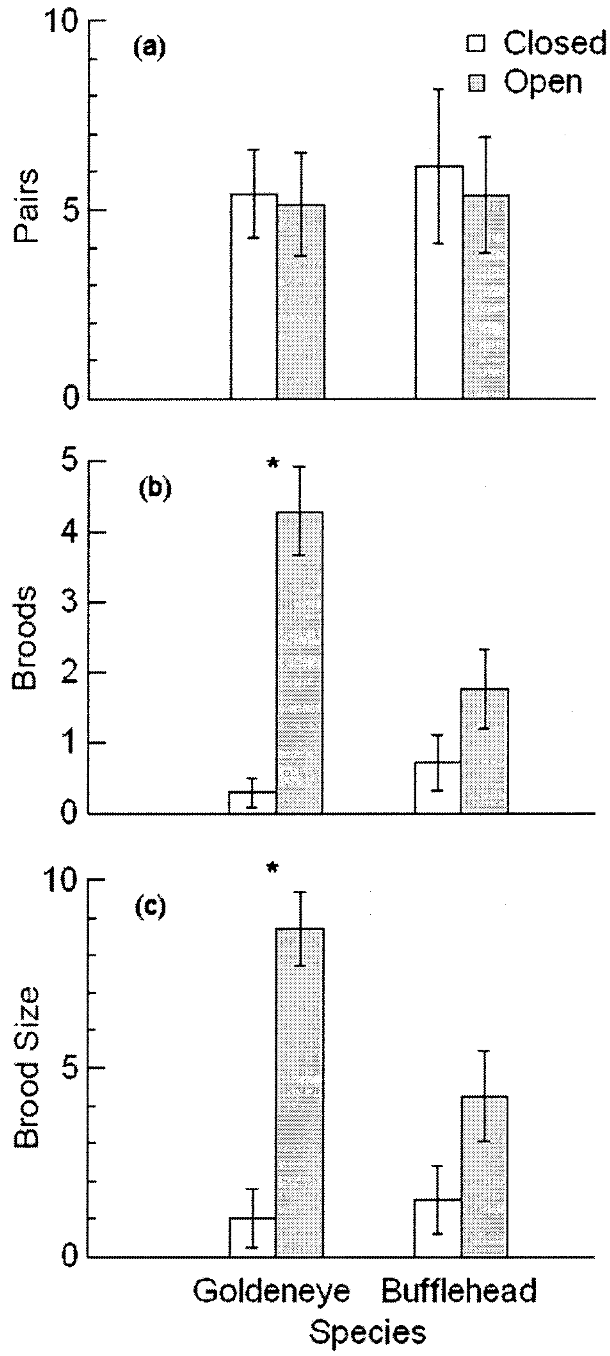

Figure 2.8: Comparison of mean (± SE) number pairs (a), broods (b), and brood size (c) of Common Goldeneye and Bufflehead in 2004 from clusters of waterbodies where nest boxes were open (grey) or closed (white) to occupancy in the Buffalo Lake Moraine, 2004. * = statistically significant ($p<0.05$).

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Comparisons of habitat characteristics within open and closed clusters of wetlands.

Comparisons of deciduous forest area (ha) and perimeter of forested uplands (km) were conducted to demonstrate there were no differences in available natural nesting habitat between open and closed clusters. Wetland area, wetland perimeter and the number of wetlands in open and closed clusters were compared to evaluate if differences existed in potential foraging and brood rearing habitat between open and closed clusters. Comparisons of habitat variables between open and closed clusters revealed no significant differences in the amount of deciduous forest (ha) within the uplands of open and closed clusters, perimeter (km) of deciduous forest of associated upland forested areas, wetland area (ha), perimeter of wetlands (km) or the number of class III – V wetlands (Table 2.5). As a result, the differences in the number and size of Common Goldeneye and Bufflehead broods between wetlands where nest boxes were available for occupancy is likely due to the manipulation of nest box availability rather than differences in characteristics of habitat associated with the clusters of wetlands. Specific habitat variables for each cluster can be found in Appendix 2.7.

Table 2.5: Comparison of mean (± SE) habitat surrounding waterbodies that supported nest boxes that were open or closed to occupancy by Common Goldeneye and Bufflehead in the Buffalo Lake Moraine, Alberta in 2004. Analyses were completed using Wilcoxon Rank Sum test (z scores) using 7 open and closed clusters for Common Goldeneye (COGO) and 8 (open) and 7 (closed) clusters for Bufflehead (BUFF). ha = hectares, km = kilometers.

Habitat Variable	Species	Open	Closed	Z	P
Deciduous cover (ha)	COGO	7.89 ± 5.34	9.55 ± 5.22	0.89	0.37
	BUFF	6.13 ± 2.28	13.98 ± 6.21	0.75	0.46
Deciduous perimeter (km)	COGO	4.51 ± 2.69	5.39 ± 2.13	1.15	0.25
	BUFF	3.64 ± 1.18	7.24 ± 2.59	0.87	0.39
Wetlands (ha)	COGO	24.28 ± 5.26	19.09 ± 6.15	-0.51	0.61
	BUFF	22.07 ± 5.08	19.02 ± 7.23	-1.01	0.31
Wetlands perimeter (km)	COGO	13.16 ± 3.37	14.40 ± 4.77	-0.13	0.90
	BUFF	12.71 ± 3.10	14.2 ± 5.64	-0.41	0.69
Class III – V wetlands (No.)	COGO	15.14 ± 2.82	15.43 ± 3.54	0.17	0.87
	BUFF	15.25 ± 2.53	13.57 ± 3.96	-1.19	0.24

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Both Common Goldeneye and Bufflehead hens are philopatric and will return to nesting locations used in prior years, especially if they were successful in previous breeding attempts (Dow and Fredga, 1983, Dow and Fredga 1985, Savard and Eadie 1989 and Gautier 1990). During the 2005 breeding season, I assessed the occupancy of 32 Common Goldeneye nest boxes that had remained open during the 2004 breeding season and 34 Common Goldeneye nest boxes that were closed during the 2004 breeding season. Of the 32 boxes that were open in 2004, 28 were occupied in 2005 (Table 2.6). Similarly, 26 of the 34 boxes, which were closed in 2004, were occupied in 2005 (Table 2.6). Occupancy rates in 2005 of previously open versus closed nest boxes, did not differ significantly ($X^2_{0.05,1}$=1.35, P=0.25). Occupancy rates for the 2005 breeding season were lower than observed occupancy rates in 2004, but were within the long-term rates previously discussed (Figure 2.7). The mean clutch size in 2004 was somewhat higher than clutch sizes found in 2005 both for boxes that remained open in 2004 or were closed in 2004 (Table 2.6).

Table 2.6: Comparison of the occupancy of nest boxes by Common Goldeneye and the mean (± SE) clutch size in the Buffalo Lake Moraine, 2004 – 2005. 2005_{Open} indicates nest boxes which were monitored in 2005 and were available for occupancy in 2004. 2005_{Closed} indicates nest boxes which were monitored in 2005 and were unavailable for occupancy in 2004.

Year	Occupied (No.)	Unoccupied (No.)	% Occupied	Mean Clutch Size (± 1 SE)
2004_{Open}	47	4	92.12	12.43 ± 0.51
2005_{Open}	28	4	87.50	11.29 ± 0.64
2005_{Closed}	26	8	76.47	12.04 ± 0.88

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DISCUSSION

My results indicate that both Common Goldeneye and Bufflehead population trajectories differ from other waterfowl and waterbird species and that population trends for these 2 species are noticeably different at the regional and local spatial scales. Due to evidence from nest box occupancy rates and results from the nest box manipulation, the availability of natural nest sites is likely limiting the production of Common Goldeneye and Bufflehead in the Buffalo Lake Moraine.

Within Stratum 26, densities of all waterfowl species with the exception of Canvasback, Common Goldeneye and Bufflehead were negatively related to year, albeit not statistically significant. Gadwall, Blue-winged Teal, Northern Pintail and Lesser Scaup, as well as sub-totals for dabblers, divers and all ducks displayed particularly strong negative correlations with year. Densities of American Coot also declined within Stratum 26 throughout the study period.

Within the Buffalo Lake Moraine itself, many species of both divers and dabblers demonstrated strong negative correlations with year. Among waterbirds, Red-necked Grebe densities declined, with Horned Grebe also demonstrating a strong negative relationship with year. Common Goldeneye and Bufflehead were the only two species, which exhibited positive population growth in the Buffalo Lake Moraine. Thus compared to general patterns for other waterfowl and waterbird species, temporal trends suggest that Common Goldeneye and Bufflehead within Stratum 26 the Buffalo Lake Moraine are responding to different key environmental features.

Within the prairie pothole region the positive relationships between spring waterfowl density and wetland density have been documented at a large spatial scale (Batt *et al.* 1989). Studies conducted at smaller spatial scales have found variable results, which were often species-specific. Leitch and Kaminski (1985) found that the number of Mallards was not significantly correlated with wetland density in study sites in Saskatchewan. A similar trend was reported by Austin (2002) who found that

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wetland density alone was not a good indicator of waterfowl abundance for a variety of dabbler species. My study indicated that wetland density at a regional scale explained more variation in dabbling ducks than for the same species guild at a smaller scale, albeit only marginally. Although not statistically significant, both Green-winged Teal and Northern Pintail were strongly correlated with wetland density regionally. Densities of these same two species displayed no relationship with wetland density within the Buffalo Lake Moraine, with Mallard being the only dabbling duck species that was strongly correlated with wetland density locally. My results suggest that wetland density explained very little of the variation in population densities for dabbling ducks at a regional or local scale.

In contrast, both regionally and locally, the density of several diving duck and waterbird species was positively and significantly related to wetland density. Kantrud and Stewart (1977) found that the divers and dabblers predominately occupied different basin types, with dabblers showing a strong preference for seasonal wetlands and divers occupying semi-permanent wetlands. Niemuth and Solberg (2003) found that the distribution of waterbirds in the prairie pothole region was strongly influenced by wetland density. Both Redhead and Canvasback were positively correlated with wetland density at a regional scale. Locally, densities of both Common Goldeneye and Bufflehead were unrelated to wetland density while densities of all other species of diving ducks were significantly related to wetland density. Densities of all waterbird species were also positively correlated with wetland density, albeit not significantly. Many factors can affect the settlement patterns of birds into suitable breeding habitats, and the high proportion of semi-permanent and permanent wetlands in the Buffalo Lake Moraine likely explains the greater predictive power of regression models for diving ducks, as the majority of wetlands in the Buffalo Lake Study area are in fact semi-permanent and permanent wetlands. The differences observed for density patterns between Common Goldeneye, and to a lesser extent Bufflehead, compared to other diving ducks and waterbirds species indicates different factors are likely driving *Bucephala spp.*

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populations within Buffalo Lake Moraine. These observations are consistent with (the importance of) nest-site availability in determining densities of *Bucephala spp*.

The local landscape of the Buffalo Lake Moraine comprised only 1.44% of the regional landscape Stratum 26. If the Buffalo Lake Moraine is representative of the entire stratum, we could assume that waterfowl populations should be representative as well. When I examined the mean percentage of waterfowl of breeding in the Buffalo Lake Moraine versus the remainder of the stratum, percentages for all species were greater than the expected 1.44%. By far Common Goldeneye displayed the greatest reliance on Buffalo Lake Moraine (Figure 2.6). Almost 12% of the spring Common Goldeneye population in Stratum 26 settles in this landscape. With exception of Common Goldeneye, waterfowl in the Buffalo Lake Moraine accounted for between 1.89% and 5.34% of regional populations. The fact that Common Goldeneye in the Buffalo Lake Moraine accounts for such a large proportion of the regional population, again differentiates this species from all others in this study. The reliance on the Buffalo Lake Moraine by Bufflehead is not different from that of other waterfowl species.

Historically, within the Buffalo Lake Moraine, increased densities of Common Goldeneye were highly correlated with increased occupancy rates of nest boxes. In 1993, the fifth year when boxes were available, occupancy reached approximately 72% and occupancy has ranged between 72 – 94% since then. By 1993, densities of breeding pairs of Common Goldeneye had doubled when compared to surveys conducted in 1989 and 1991. The highest rate of Common Goldeneye occupancy occurred in 2001, which also corresponds to the highest recorded density of breeding pairs documented in the Buffalo Lake Moraine. Correlation between nest box occupancy and increases in breeding pair density provides further evidence for the reliance of Common Goldeneye on nest boxes in the Buffalo Lake Moraine. Increased densities of Bufflehead also correspond with increased rates of nest box occupancy by this species, although the relationship is weaker. Occupancy increased between 1991 and 1993 and has since stabilized with rates remaining between

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approximately 30 – 60 %. As occupancy rates stabilized, breeding densities of Bufflehead also increased, although the pattern was not as pronounced as for Common Goldeneye. As previously mentioned, female *Bucephala spp,* are highly philopatric and will readily return to successful nesting areas. When nest boxes were reopened in 2005, they were readily occupied (76.5%), again providing further evidence that available nest sites are limiting in the Buffalo Lake Moraine.

I predicted that Common Goldeneye and Bufflehead would utilize nest boxes in the Buffalo Lake Moraine because reproduction of both species was limited by the availability of naturally occurring nest cavities. I tested this prediction by designing an experiment where nest boxes were systematically closed within some clusters of waterbodies while nest boxes in other clusters remained open. I predicted that the exclusion of female Common Goldeneye and Bufflehead from man-made nest sites the distribution of pairs would not be affected, however, there would be a reduction in the number of broods between cluster types. In fact, the experimental closure of existing nest boxes did not influence the number of Common Goldeneye pairs that occupied clusters of wetlands. Closure significantly reduced numbers of broods and sizes of broods occupying wetlands with closed nest boxes. This result is consistent with my analysis of regional and local survey data and supports that availability of natural nest sites is limiting population growth of Common Goldeneye in the Buffalo Lake Moraine and the provision of nest boxes is driving population density. As was true for Common Goldeneye in my manipulation, the availability of nest boxes did not influence the occupancy of waterbodies by Bufflehead pairs. Although, not as strong when compared to Common Goldeneye, there was an effect of nest box availability on the number and size of Bufflehead broods.

The lack of difference in habitat characteristics between wetland clusters with open versus closed nest boxes provided strong evidence that differences in numbers of broods and brood size arose directly from the manipulation of nest boxes. Other studies of nest boxes and *Bucephala spp.,* have demonstrated that nest boxes can effectively increase breeding population (Coulter 1979, Dennis and Dow 1984,

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Savard 1988 and Poysa and Poysa 2002). Poysa and Poysa (2002) suggest that provisioning of nest boxes can increase breeding populations, but that density dependence during nesting and brood rearing may result in lower numbers of fledged birds. Several density-dependent mechanisms, which could limit reproductive output, may exist. Nest parasitism and territoriality have been suggested as possible factors that may limit population growth of *Bucephala spp.*, (Savard 1982, Gautier 1987, Savard, Smith and Smith 1991, and Evan et al. 2002). Through the temporal analysis of population and nest box occupancy data, as well as the manipulation results, I suggest that nest site availability is the primary limitation for Common Goldeneye, and to a lesser extent Bufflehead, in the Buffalo Lake Moraine.

Previous studies have demonstrated the ability of nest boxes to increase local populations of breeding cavity-nesting waterfowl for a variety of species and landscapes (Strange et. al 1971, Bellrose 1980, Gautier and Smith 1987). Deployment of nest boxes can also establish breeding populations of Common Goldeneye in areas where the species was present but not reproducing (e.g., Coulter 1979, Dennis and Dow 1984). To the best of my knowledge, my study is the first to examine the utility of nest boxes to increase the abundance of cavity-nesting waterfowl species within the aspen parkland eco-region.

Use of nest boxes to increase populations of both Common and Barrow's Goldeneye *(Bucephala islandica)* is well documented, however effects on Bufflehead populations are less well known. Gauthier and Smith (1987) found that while Bufflehead preferred artificial nest boxes to natural cavities, the addition of nest boxes did not increase local populations in the Cariboo Parklands of British Columbia. In the same geographic area, Evans *et* al., (2002) found that clutch sizes produced by Barrow's Goldeneye and Bufflehead that occupied nest boxes did not differ from those that occupied natural cavities. My study found that the temporary closure of nest boxes did not significantly alter the number of broods or brood size for Buffleheads, suggesting that the provision of nest boxes may have only a marginally positive effect on local populations within the Buffalo Lake Moraine. My

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observations that the availability of nest sites affects reproductive output of Common Goldeneye to a greater degree than Bufflehead could be related to differences in nest size requirements between the two species. Bufflehead are known to use small cavities such as those excavated by Northern Flicker (*Colaptes auratus)* whereas, Common Goldeneye need larger cavities typically excavated by Pileated Woodpecker *(Dryocopus pileatus)*. In the aspen parkland eco-region of central Alberta, Northern Flickers were recorded on 52% of blocks surveyed whereas Pileated Woodpeckers were recorded on only 15% of the same blocks (Semenchuk 1993). The difference in the long-term nest box occupancy rates between the two *Bucephala spp*., likely reflects the difference in the availability of natural nest sites.

Numerous studies have shown that clutch size of Common Goldeneye is moderately variable. Eadie et. al (1995) completed a detailed compilation of clutch sizes produced by Common Goldeneye in North America and northern Europe and found that Common Goldeneye typically produced between 7.4 to 10.3 eggs per nest. By contrast, results from my study suggested that clutch size of Common Goldeneye in the Buffalo Lake Moraine (12.02 ± 0.38) was at least 14% higher than values reported by these studies and is the highest recorded to date. During the 2004 and 2005 breeding seasons, 58% of all occupied nests boxes in the Buffalo Lake Moraine contained nests with 12 or more eggs. Ahlund (2005) found that approximately 70% of Common Goldeneye nests in his study area were parasitized and eggs laid by nest parasites accounted for approximately 35% of all eggs. In northern Ontario, Mallory (1994) found that nest with > 11 eggs typically resulted from nest parasitism, where eggs were laid by at least two different females. Although I did not test for brood parasitism, the high mean clutch size found in the Buffalo Lake Moraine is likely due in part to conspecific nest parasitism. Evans et al (2002) speculated that use of nest boxes and subsequent nest parasitism might create population sinks for Barrow's Goldeneye by attracting increased densities of breeding pairs which experience high levels of competition for available nest sites and subsequent parasitism. Additional research regarding nest parasitism is required to determine if high clutch sizes may negatively impact production of Common Goldeneye in the Buffalo Lake Moraine.

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Management Implications and Future Research

The aspen parkland ecoregion of central Alberta has undergone significant habitat alterations and the direct loss of wetland and upland habitat over the last century. These changes have undoubtedly impacted waterfowl and waterbird populations within the Buffalo Lake Moraine. It is well documented that nesting success is a primary determinant of the size of waterfowl populations (Cowardin and Johnson 1979). Further, numerous studies suggest that nest success in the prairie pothole region is currently too low to sustain continental waterfowl populations (Cowardin et. al 1985, Klett et. al 1988, Grenwood et. al 1994). Waterfowl are highly philopatric and prefer to return to their natal site to breed when wetland and nesting conditions are favorable (Bellrose 1980). My analysis at both the regional and local scales has shown that densities for most species' displayed negative trends over the 16 year period between 1989 and 2004. Additional research is required to understand the population dynamics of waterfowl species in the Buffalo Lake Moraine, if the conservation of waterfowl is a priority management goal.

Both Common Goldeneye and Bufflehead were present in the Buffalo Lake Moraine prior to the deployment of nest boxes (Murphy et. al 2003). Breeding densities for both of these species have increased since provision of nest boxes, although to varying degrees. My study demonstrated that recent increases in densities of Common Goldeneye in the Buffalo Lake Moraine coincide with increases in nesting sites provided through deployment of nest boxes. The extent that current densities of *Bucephala spp.* will increase with the installation of additional nest boxes is unknown. It is possible that additional positive population responses may be dampened by density dependent factors, such as food resource availability and territorial behavior. Irrespective of results from further increases in populations of Common Goldeneye, my data suggest that nest boxes represent an effective means of establishing, enhancing and sustaining Common Goldeneye populations in the aspen parkland ecoregion.

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Appendix 2.1: Estimated density (number/km^2) of spring breeding waterfowl in Stratum 26 in central Alberta, 1989 – 2004.

	Year								
Species	**1989**	**1991**	**1993**	**1995**	**1997**	**1999**	**2001**	**2003**	**2004**
Mallard	4.25	5.66	4.42	5.37	5.04	7.25	5.11	3.65	3.50
Gadwall	2.02	2.01	2.66	2.69	2.14	2.45	2.21	1.15	1.33
American Wigeon	0.66	0.85	1.26	1.13	1.15	0.76	0.81	0.66	0.71
Green-Winged Teal	0.83	1.04	1.45	1.86	2.60	1.53	1.30	0.70	0.72
Blue-Winged Teal	3.04	4.92	3.42	2.60	2.32	2.79	3.21	1.81	2.15
Northern Shoveler	1.48	2.35	2.12	1.53	2.20	2.24	1.99	1.34	1.85
Northern Pintail	0.74	0.74	0.78	0.69	1.56	0.56	0.35	0.42	0.33
Sub-total Dabblers	13.01	17.57	16.10	15.87	17.02	17.58	14.98	9.73	10.59
Redhead	0.86	0.89	0.89	0.82	1.60	1.72	0.35	0.55	0.42
Canvasback	0.31	0.55	0.37	0.49	0.58	0.47	0.27	0.49	0.43
Lesser Scaup	1.36	2.62	2.09	2.88	2.67	1.88	1.64	1.09	0.58
Common Goldeneye	0.16	0.08	0.08	0.34	0.08	0.02	0.24	0.29	0.16
Bufflehead	0.35	0.83	0.83	0.70	0.89	0.72	0.62	0.77	0.65
Ruddy Duck	0.68	1.15	0.23	0.50	0.61	0.62	0.34	0.47	0.80
Sub-total Divers	4.07	6.21	4.57	5.80	6.54	5.80	3.59	3.70	3.23
Total Ducks	17.08	23.78	20.68	21.67	23.55	23.38	18.57	13.43	13.82
American Coot	2.75	1.89	2.20	1.43	2.16	2.22	1.08	0.92	0.89

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Appendix 2.2: Estimated density (number/km^2) of spring breeding waterfowl in the Buffalo Lake Moraine in central Alberta; 1989 – 2004.

	Year								
Species	**1989**	**1991**	**1993**	**1995**	**1997**	**1999**	**2001**	**2003**	**2004**
Mallard	16.37	23.82	19.44	23.48	18.59	19.54	18.19	8.83	9.17
Gadwall	9.19	15.01	12.88	13.04	12.06	11.58	12.01	6.19	12.93
American Wigeon	2.84	3.80	2.84	5.30	2.65	2.94	4.55	0.76	2.12
Green-Winged Teal	1.86	5.76	3.25	5.93	3.76	2.68	7.18	1.70	3.40
Blue-Winged Teal	20.01	34.88	21.78	21.37	19.67	18.15	19.57	8.52	10.53
Northern Shoveler	6.50	11.05	7.35	6.42	3.76	6.47	13.01	2.97	6.65
Northern Pintail	1.70	3.03	2.76	2.37	0.95	1.07	1.42	0.35	1.09
Sub-total Dabblers	59.39	98.39	71.35	78.72	62.59	63.24	76.58	29.58	45.93
Redhead	4.56	7.43	7.70	8.29	6.57	7.23	7.84	4.20	2.06
Canvasback	3.06	2.24	2.78	1.80	1.83	2.21	1.55	1.36	0.22
Lesser Scaup	11.43	11.84	14.54	16.32	14.33	12.59	12.99	5.10	2.18
Common Goldeneye	0.88	0.73	1.67	3.16	3.12	3.82	4.48	4.23	2.28
Bufflehead	2.27	2.11	3.19	4.26	3.82	4.10	4.64	4.07	3.06
Ruddy Duck	1.09	4.85	4.42	4.55	5.73	3.08	2.86	1.96	0.28
Sub-total Divers	23.75	29.40	34.90	38.51	35.83	33.38	35.02	21.02	10.27
Total Ducks	83.14	127.79	106.25	117.23	98.42	96.62	111.60	50.60	56.20
American Coot	2.73	9.78	13.90	13.18	13.90	9.67	8.19	3.62	0.12
Horned Grebe	2.09	2.53	3.12	2.43	2.12	1.79	2.78	1.64	0.27
Red-necked Grebe	0.51	0.66	0.53	0.39	0.66	0.37	0.27	0.22	0.06
Eared Grebe	0.05	0.34	0.17	0.27	0.17	0.27	0.23	0.12	0.44

Appendix 2.3: Location and linear distance (km) of individual clusters and the mean (± *SE*) linear distance for Common Goldeneye open and closed clusters within the Buffalo Lake Moraine study area for the 2004 nest box manipulation.

Cluster	Nest Boxes (open/closed)	Transect	Start Latitude	Start Longitude	Finish Latitude	Finish Longitude	Distance (km)
A	Closed	1	52.34689	112.95470	52.34686	113.03243	5.30
C	Closed	2	52.40506	112.82394	52.40514	112.96688	9.73
E	Closed	3	52.46321	112.64282	52.46312	112.68738	3.03
G	Closed	4	52.52128	112.71465	52.52158	112.74642	2.16
I	Closed	5	52.57992	112.79388	52.57994	112.93447	9.53
K	Closed	5	52.57946	113.12271	52.57938	113.13351	0.73
M	Closed	6	52.63800	112.85861	52.63797	112.89957	2.77
					Mean (± 1 SE)		***4.75 ± 1.36***
B	Open	2	52.40485	112.73871	52.40245	112.76286	1.67
D	Open	2	52.40515	113.05104	52.40460	113.14501	6.39
F	Open	4	52.52136	112.64351	52.52132	112.70018	3.85
H	Open	5	52.57974	112.61917	52.57997	112.76761	10.06
J	Open	5	52.57960	113.02180	52.57957	113.05049	1.94
L	Open	6	52.63787	112.78673	52.63795	112.84761	4.12
N	Open	6	52.63802	112.91862	52.63735	113.12471	13.95
					Mean (± 1 SE)		***6.00 ±1.71***

Appendix 2.4: Location and linear distance (km) of individual clusters and the mean (± *SE*) linear distance (km) for Bufflehead open and closed clusters within the Buffalo Lake Moraine study area for the 2004 nest box manipulation.

Cluster	Nest Boxes (open/closed)	Transect	Start Latitude	Start Longitude	Finish Latitude	Finish Longitude	Distance
I	Closed	1	52.34695	112.97892	52.34686	113.03243	3.65
III	Closed	2	52.40506	112.82394	52.40515	113.07471	17.06
V	Closed	3	52.46309	112.70315	52.46316	112.71881	1.06
VIII	Closed	4	52.52128	112.71465	52.52158	112.74642	2.16
X	Closed	5	52.57992	112.79388	52.57994	112.93447	9.53
XII	Closed	5	52.57946	113.12271	52.57938	113.13351	0.73
XIV	Closed	6	52.63800	112.85861	52.63797	112.89957	2.77
						Mean (± 1 SE)	***5.28 ± 2.56***
II	Open	2	52.40485	112.73871	52.40245	112.76286	1.67
IV	Open	3	52.46321	112.64282	52.46312	112.68738	3.03
VI	Open	3	52.46321	112.75668	52.46325	112.80354	3.18
VII	Open	4	52.52132	112.59503	52.52132	112.70018	7.14
IX	Open	5	52.57974	112.61917	52.57997	112.76761	10.06
XI	Open	5	52.57960	113.02180	52.57956	113.08662	4.38
XIII	Open	6	52.63787	112.78673	52.63795	112.84761	4.12
XV	Open	6	52.63802	112.91862	52.63735	113.12471	1.39
						Mean (± 1 SE)	***4.37 ± 1.03***

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Appendix 2.5: Number of available nest boxes monitored, the number of occupied nest boxes and percentage of available boxes occupied for Common Goldeneye (COGE) and Bufflehead (BUFF) in the Buffalo Lake Moraine (1989 –2005).

	No. Boxes Monitored		No. Boxes Occupied		Nest Box Occupancy (%)	
Year	COGE	BUFF	COGE	BUFF	COGE	BUFF
1989	185	-	11	-	5.9	-
1990	189	-	37	-	19.6	-
1991	190	40	64	3	33.7	7.5
1992	191	78	102	7	53.4	9.0
1993	191	80	139	10	72.8	12.5
1994	190	80	155	25	81.6	31.3
1995	188	80	166	32	88.3	40.0
1999	189	80	155	45	82.0	56.3
2001	173	65	165	38	95.4	58.5
2002	185	80	165	40	89.2	50.0
2003	-	34	-	16	-	47.1
2004	51	33	47	10	92.2	30.3
2005	66	38	54	14	81.8	36.8

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Appendix 2.6: Habitat variables for individual clusters within the Buffalo Lake Moraine study area for the 2004 nest box manipulation. Clusters which are identified by letters represent Common Goldeneye and clusters identified by numbers represent Bufflehead.

Cluster	Deciduous Area (ha)	Deciduous Perimeter (km)	Wetland Area (ha)	Wetland Perimeter (km)	Class III – V Wetlands
A	40.47	17.67	15.04	14.93	10
C	0.97	1.37	37.63	35.26	34
E	2.80	2.07	9.99	4.63	16
G	3.13	2.60	8.80	4.67	10
I	5.83	4.27	45.82	26.47	14
K	5.99	3.77	1.65	0.90	5
M	7.66	5.99	14.71	13.94	19
mean (± 1 SE)	***9.55 ± 5.22***	***5.39 ± 2.13***	***19.09 ± 6.15***	***14.40 ± 4.77***	***15.43 ± 3.54***
B	0.69	0.60	7.08	4.78	14
D	39.28	19.98	21.51	12.22	9
F	1.31	0.75	12.94	7.65	10
H	3.67	2.46	50.20	31.54	24
J	1.03	0.82	29.49	7.55	6
L	0.81	0.70	20.58	15.51	25
N	8.47	6.27	28.15	12.84	18
mean (± 1 SE)	***7.89 ± 5.34***	***4.51 ± 2.69***	***24.28 ± 5.26***	***13.16 ± 3.37***	***15.14 ± 2.82***
I	33.62	16.52	8.60	8.19	10
III	41.47	17.35	47.50	41.91	34
V	0.12	0.16	6.07	3.42	3
VIII	3.13	2.60	8.80	4.67	10
X	5.83	4.27	45.82	26.47	14
XII	5.99	3.77	1.64	0.90	5
XIV	7.66	5.99	14.71	13.94	19
mean (± 1 SE)	***13.98 ± 6.21***	***7.24 ± 2.59***	***19.02 ± 7.23***	***14.20 ± 5.64***	***13.57 ± 3.96***
II	0.69	0.60	7.08	4.78	14
IV	2.80	2.07	9.99	4.62	16
VI	13.83	8.79	9.31	8.97	6
VII	1.31	0.75	20.36	15.68	13
IX	3.67	2.47	50.20	31.54	24
XI	17.43	7.46	30.86	7.71	6
XIII	0.81	0.70	20.58	15.51	25
XV	8.47	6.27	28.15	12.84	18
	mean (± 1 SE)	***6.13 ± 2.28***	***3.64 ± 1.18***	***22.07 ± 5.08***	***12.71 ± 3.10***

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Appendix 2.7: Number of pairs, number of broods and brood size for individual clusters within the Buffalo Lake Moraine study area for the 2004 nest box manipulation. Clusters which are identified by letters represent Common Goldeneye and clusters identified by numbers represent Bufflehead.

Cluster	Nest Boxes (open/closed)	Number of Pairs	Number of Broods	Brood Size (mean)
A	Closed	1	0	0
C	Closed	9	0	0
E	Closed	7	1	5
G	Closed	8	0	0
I	Closed	5	0	2
K	Closed	5	0	0
M	Closed	3	1	0
	mean (± 1 SE)	***5.43± 1.07***	***0.29 ± 0.18***	***1.00 ± 0.73***
		Clusters w/ Broods	***2 of 7***	
B	Open	3	5	7.60
D	Open	5	4	6.00
F	Open	2	3	6.67
H	Open	12	7	7.33
J	Open	6	5	11.57
L	Open	5	3	11.33
N	Open	3	3	10.50
	mean (± 1 SE)	***5.14 ± 1.26***	***4.29 ± 0.57***	***8.72 ± 0.88***
		Clusters w/ Broods	***7 of 7***	
I	Closed	1	0	0
III	Closed	4	0	5.5
V	Closed	1	0	0
VIII	Closed	15	1	2
X	Closed	8	0	0
XII	Closed	5	2	3
XIV	Closed	9	2	0
	mean (± 1 SE)	***6.14± 1.88***	***0.71± 0.36***	***1.5 ± 0.81***
		Clusters w/ Broods	***3 of 7***	
II	Open	2	0	0
IV	Open	1	2	1
VI	Open	4	2	5.5
VII	Open	7	1	3
IX	Open	14	5	3.4
XI	Open	5	2	8
XIII	Open	6	1	4
XV	Open	4	1	9
	mean (± 1 SE)	***5.38 ± 1.41***	***1.75 ±0.53***	***4.24 ±1.11***
		Clusters w/ Broods	***7 of 8***	

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Chapter 3

Response of waterfowl and waterbird community assemblages to increased populations of Common Goldeneye (Bucephala clangula) and Bufflehead (Bucephala albeola) in the Buffalo Lake Moraine.

INTRODUCTION

Continental waterfowl populations have decreased substantially throughout North America during the 20th century. Loss and alteration of breeding habitat have been widely attributed as primary factors contributing to these declines (Baldassarre and Bolen 1994). In response to diminished waterfowl populations, the North American Waterfowl Management Plan (NAWMP) was initiated in 1989, with the goal to restore continental breeding waterfowl to levels observed during the 1970's. Activities undertaken by NAWMP, most often deal with the delivery of conservation efforts and goals measured at a landscape level. In addition to large-scale initiatives, waterfowl managers undertake a variety of activities to enhance local populations of waterfowl. One measure often utilized is the provision of artificial nesting structures aimed at increasing nesting success of specific waterfowl species. Nest boxes have been widely and successfully used to increase populations of Wood Duck (*Aix sponsa)* in areas where natural nesting habitats have been destroyed or altered (Bellrose 1976). The provision of artificial nest boxes has also been linked to increased productivity and subsequent local population increases of *Bucephala spp.* (Coulter 1979, Dennis and Dow 1984, Savard 1988, Poysa and Poysa 2002). The extent that nest boxes increase waterfowl productivity of cavity-nesting waterfowl depends, in part, on the extent that naturally occurring nesting cavities limit reproductive success.

Nest boxes have been widely used to increase densities of Common Goldeneye (*Bucephala clangula*) and Bufflehead (*Bucephala albeola*) in the Buffalo Lake Moraine regions of central Alberta where agricultural practices may have reduced the availability of natural cavities suitable for nesting. While conservation efforts to increase densities of both species have been met with success, enhanced

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populations of *Bucephala spp.* through the provision of nest boxes raise concern on whether nest box manipulations may be altering the overall structure of waterfowl and waterbird communities. Intra-specific and inter-specific territoriality and aggression have been well documented for all *Bucephala spp.* (Gauthier 1993, Eadie *et al.* 1995, Eadie *et al.* 2000). Territoriality involving Barrow's Goldeneye (*Bucephala islandica*), Common Goldeneye and Bufflehead drakes occurs during the spring breeding season and into early incubation when they are establishing and actively defending defined territories (Savard 1984). Gautier (1987) suggested that territoriality in Bufflehead was related to mate guarding and protection of nest sites from competitors. Savard (1988) proposed that the advantage for Barrow's Goldeneye territorial behavior is the provision of exclusive and undistributed feeding areas for a male's mate. Thompson and Ankney (2002) concurred with Savard and suggested that food defense is the most likely explanation for intra and inter-specific aggression involving *Bucephala spp.* Inter-specific territoriality and aggression in areas of sympatry occurs more frequently with congeners than with waterfowl species of different genera (Savard 1982, Savard 1984). Inter-specific aggression involving *Bucephala spp.* has the potential to impact community structure and the provision of nest boxes may in fact have potentially deleterious effects associated with increased densities of targeted waterfowl.

In Chapter 2, I demonstrated that increased densities of Common Goldeneye and Bufflehead over the last decade have been linked to the provision of nest boxes. In this chapter, I broadly address the question of whether increases in the abundance of Common Goldeneye and Bufflehead influence the overall structure of waterfowl and waterbird communities in the Buffalo Lake Moraine. To assess the response of waterfowl and waterbird communities to increased breeding populations of Common Goldeneye and Bufflehead, my approach was 3-fold. First, using presence/absence of breeding waterfowl and waterbirds, and the presence/absence of waterfowl and waterbird broods, I tested for associations between the composition of waterfowl and waterbird assemblages and environmental variables in the Buffalo Lake Moraine. Second, I tested for concordance in the structure of waterfowl and waterbird

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communities on study area wetlands before (1989) and after (2003) densities of Common Goldeneye and Bufflehead increased in response to nest boxes. Third, I conducted focal animal behavioural sampling of Common Goldeneye and Bufflehead in the Buffalo Lake Moraine to examine intra and inter-specific aggression that may explain patterns in community structure.

I predicted that waterfowl and waterbird communities will be organized as foraging guilds (i.e. dabblers vs. divers and waterbirds) and will be related to environmental variables, which are associated with specific feeding and nesting requirements. Secondly, I predicted that the composition of waterfowl and waterbird assemblages on Buffalo Lake Moraine wetlands have been altered due to increased densities in Common Goldeneye and Bufflehead. Lastly, I predicted that aggression involving Common Goldeneye and Bufflehead directed towards other species of waterfowl and waterbirds would offer a plausible mechanism explaining observed alterations in assemblage composition.

METHODS

Study Area

Located in the aspen parkland eco-region of central Alberta, the Buffalo Lake Moraine (BLM) study area is recognized as one of the most significant landscapes for breeding waterfowl in Alberta (Anonymous 1989). The BLM study area encompasses approximately 1,300 km^2 and is located primarily in the County of Stettler and adjacent municipalities (52.2 –52.4 °N, 112.4 – 113.1 °W, Figure 3.1). The area is characterized by knob and kettle topography. Wetland density can exceed 20 wetlands per km^2. The aspen parkland eco-region, dominant in BLM, is characterized by groves of aspen (*Poplus tremuloides)*, balsam poplar (*Poplus balsmifera)* and willow (*Salix spp.)* intermixed with grasslands dominated by rough fescue *(Festuca scrabrella)* (Bailey and Wroe 1974). Approximately 5% of the land base remains in vegetation communities similar to those present prior to European settlement, with agricultural expansion and intensification being identified as the primary reason for this high rate of alteration (Van Tighem 1993).

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In 1989 the Prairie Habitat Joint Venture (PHJV) program was developed to guide the implementation of NAWMP activities. Within Alberta, three priority areas were identified as targets for the PHJV program; the prairie biome, the aspen parkland biome and the Peace parkland biome with the aspen parkland being selected as the major focus area (PHJV 1989). In response to commencement of the First Step Project under guidance of the PHJV, the Alberta Government's Fish and Wildlife Division, conducted waterfowl pair and brood surveys in BLM between 1989 – 2003 (Allen 1989). Waterfowl pair and brood surveys were completed every second year between 1989 and 2003, for a total of 8 survey years. The analysis of community waterfowl and waterbird data for Chapter 3 was completed using waterfowl and waterbird pair and brood data collected in 1989 and 2003.

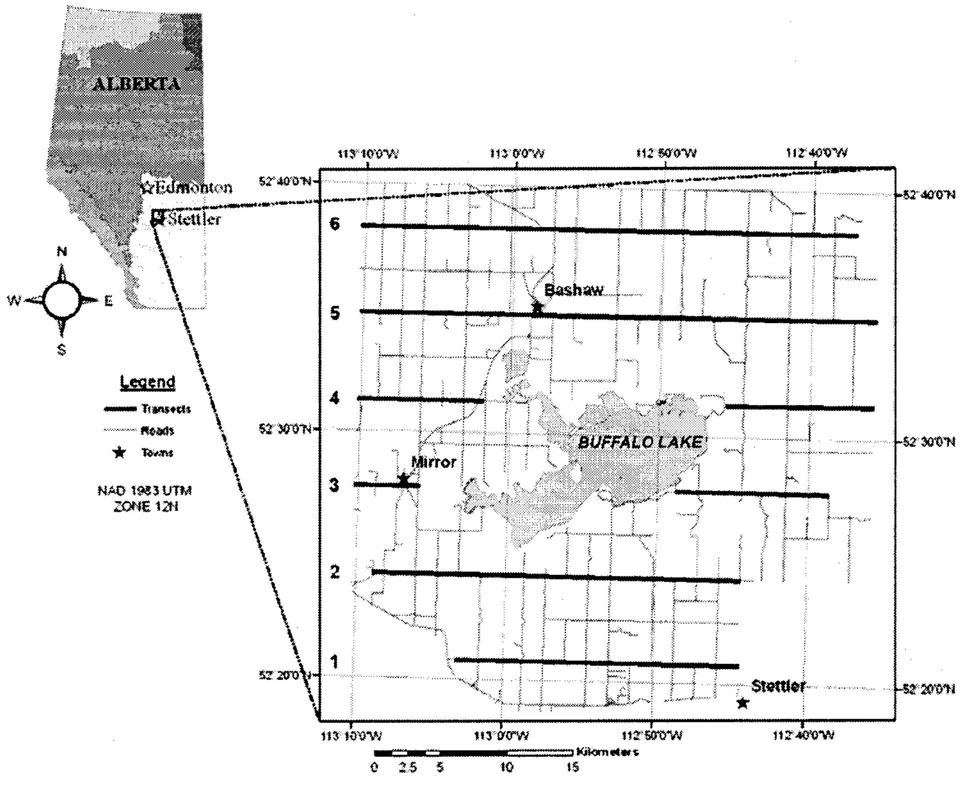

Figure 3.1: Location of the six road-side transects surveyed to quantify waterfowl and waterbird communities in wetlands in the Buffalo Lake Moraine, in east central Alberta. Transects are identified by horizontal lines extending west to east.

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Waterfowl and Waterbird Pairs and Broods

I analyzed data describing the presence of waterfowl and waterbird pairs and broods collected on wetlands along 6 east-west road transects in 1989 and 2003 as a component of the Buffalo Lake Moraine Waterfowl and Wetland Surveys (Allen 1989). The total length of all 6 transects encompassed 159.32 km and included 93.33 km along four gravel township roads, 27.37 km along one tertiary highway and 38.62 km along 1 secondary highway and 1 transect is a tertiary highway (Figure 3.1). Transects 1 and 2 are located south of Buffalo Lake, whereas transects 3 and 4 are located on both the east and west side of Buffalo Lake and transects 5 and 6 are located north of Buffalo Lake. All wetlands <200 m north and south of the transect lines were surveyed for waterfowl and waterbirds. Specific locations of the 6 transects are provided in Appendix 3.1.

Two surveys of waterfowl and waterbird pairs and 2 brood surveys were conducted in each survey year. Initial breeding waterfowl and waterbird surveys were completed during May (4 to 26 May, 1989 and 9 to 16 May, 2003) and the second survey conducted in June (1 to 8 June, 1989 and 2 to 6 June, 2003). Waterfowl and waterbird brood surveys were completed in July (4 to 7 July, 1989 and 2 to 9 July, 2003) and August (1 to 8 August, 1989 and 5 to 7 August, 2003). Surveys completed in each year were conducted using identical methods with the same crew leader (Jim Potter, Alberta Conservation Association, Red Deer, Alberta, pers comm.) responsible for data collection, ensuring that identical standards and protocols were employed for data collection. I was personally involved in the data collection during the 2003 survey.

Waterfowl and waterbird pair and brood surveys were initiated at sunrise (approximately 5:00 am Mountain Daily Standard Time (MDST)) and were concluded at approximately 12:00 noon (MDST) of each day, or earlier if precipitation or wind speed limited visibility. Surveys were conducted in a westerly direction to minimize glare from the sun, and consisted of stops (2 – 15 minutes) at each wetland to record bird abundance. Observations continued for longer periods on

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larger and more structurally diverse wetlands. Observations were made from trucks or viewpoints adjacent to wetlands with the use of spotting scopes and binoculars. If observers could not adequately view the entire wetland from the road, they walked the perimeter around wetlands in an attempt to increase sight ability.

Initially waterfowl were classified according to standard spring waterfowl survey procedures (Anonymous 1987). Specifically, waterfowl were classified and recorded as: 1) lone drakes and hens, 2) pairs, 3) flocked drakes and 4) grouped drakes. Additionally, I analyze and discuss the occurrence of select waterbird species; specifically Red-neck Grebe (*Podiceps grisegena)*, Horned Grebe (*Podiceps auritus*) and American Coot (*Fulica americana*). The presence of waterfowl and waterbird species on wetlands during spring surveys were analyzed as presence/absence data. For each brood survey, all young were identified, counted and aged according to plumage development as described by Gollup and Marshall (1954). However, for the purpose of this study, brood data was analyzed as presence/absence data for each study area wetland.

Habitat Data

Environmental data describing wetlands was collected through a combination of field assessments and assessments of digitized aerial photography (1989) with ArcGIS 9.0. Field-based collection of habitat data occurred in conjunction with the initial pair survey conducted in 1989 and 2003. Variables collected through field surveys included: wetland type (TYPE), water level (LEVEL), margin width (MARGIN) and upland condition (UPLAND). Wetland types were classified based on the capacity to retain water throughout the spring and summer periods (Stewart and Kantrud 1971). Wetlands were classified into the following to categories: Dry, Class I, Class III, Class IV and Class V. A detailed description of wetland types is found in Table 3.1. Individual wetlands were assessed to describe current water level (Didiuk *et al.* 1989) and classified into categories ranging from level 1 to 7 (Table 3.2). Estimates of the percentage of wetland perimeter (to 10m) that was uncultivated for each wetland basin were collected for individual wetlands. Finally, the condition

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of uplands adjacent to each wetland was assessed based upon the percentage of each upland condition category immediately adjacent to the wetland basin. Descriptions of upland classifications can be found in Table 3.3. Upland condition categories were: 1) wooded, 2) grasslands, 3) crop, 4) farm yard and 5) permanent cover. A summary of habitat data collected for wetlands used in the analysis of community data is provided in Appendix 3.2.

Table 3.1: Description of wetland types used to classify basins in the Buffalo Lake Moraine study area. Wetland types are taken form Stewart and Kantrud (1971).

Wetland Type	Description
Dry	No surface water present in basin
Class I	Ephemeral, surface water present for < 3 weeks
Class III	Seasonal, surface water present for > 3 weeks and usually dry by July
Class IV	Semi-permanent, surface water estimated to persist until September-October in 7 out of 10 years
Class V	Permanent, surface water persisting throughout the year, except in periods of severe drought

Table 3.2: Description of water levels used to classify current wetland conditions in the Buffalo Lake Moraine study area. Water level descriptions are from Didiuk *et al.* (1989).

Water Level	Description
Level 1	Dry, no visible surface water
Level 2	Vestigial, small puddles, disappears <1 week
Level 3	Recessional, water levels receded with mud flats exposed
Level 4	Intermediate, water levels receded to emergent vegetation
Level 5	Full, surface water present extending to the wet meadow zone
Level 6	Flooded, surface water extending into the uplands, remaining in wetland basin
Level 7	Overflowing, surface water flowing out of wetland basin

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Table 3.3: Description of classifications used to describe dominant upland condition adjacent to study area wetlands in the Buffalo Lake Moraine.

Upland Condition	Description
Wooded	Both ungrazed and grazed uplands dominated by woody vegetation.
Grass	Native grasslands with no grazing.
Crop	Land currently used for the production of annual crops, activities include: cultivation, stubble, crop and fallow fields.
Farm Yard	Uplands with the presence of house and/or buildings used for farming.
Permanent Cover	Lands that are currently being used for grazing or haying of tame or native grasses.

Using aerial photographs from 1989, individual wetlands were geo-referenced and digitized to determine area (ha), perimeter (m) and location. Wetlands were identified from original study area transects maps and retained unique identification numbers. Habitat variable data collected through Geographic Information System (GIS) queries included: wetland area (AREA), wetland perimeter (PERIM), location (NORTHING AND EASTING), a perimeter to area ratio (PER:AREA) and proportion of wetlands (PROPORTION). To reflect a measure of wetland shoreline structure, I calculated the perimeter to area metric (perimeter:area). I used focal statistic function in Spatial Analyst (ArcGIS 9.0) to reflect a measure of the proportion of adjacent landscape in wetlands. The proportion of the area that was classified as a wetland within a 500m radius of the center of each individual wetland was calculated. Measurements for this metric, ranged from 0 (0% of area comprised of wetlands) to 1 (100% of area comprised of wetlands). A summary of environmental variables collected through GIS can be found in Appendix 3.2.

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Statistical Analysis

I described the overall patterns of waterfowl and waterbird community structure in the Buffalo Lake Moraine using multi-variate ordination techniques. Ordination is used to represent ecological data in a 2-dimensional space, wherein similar species and/or sites are close in proximity and dissimilar species and/or sites are further apart (Gauch 1982, ter Braak 1995). Ecological data are very complex and influenced by numerous biotic and abioitc variables. Ordination allows for these complex relationships to be explored and represented graphically. Analyses were completed separately for 1989 and 2003 for the presence of individual species of: 1) breeding waterfowl and waterbirds and 2) waterfowl and waterbird broods. Analysis was completed initially with Common Goldeneye and Bufflehead included in the pair and brood ordinations and then subsequently with these species removed. For the ordinations with Common Goldeneye and Bufflehead removed, the presence of these species on wetlands was included as environmental variables. Only wetlands (n=429 for pairs and n=96 for broods) which contained at least 1 waterfowl or waterbird species in both 1989 and 2003 were included in analysis for pairs and likewise, only wetlands with the presence of at least 1 brood in both study years were included in the brood analysis. Waterfowl or waterbird species, which occurred in less than 5% of wetlands when both years were combined were considered rare species and were excluded from the community analysis. Using these criteria, Red-neck Grebe was excluded from the analysis of pair data and Green-winged Teal was excluded from analyses of brood data. As a component of the overall community analysis I compared the relationship between the presence of pairs and broods on individual wetlands. To examine the relationship between the presence of pair and the occurrence of a brood for the same species, I used a 2 x 2 contingency table and Fisher's Exact test to test for independence between the presence of pairs and broods on study area wetlands.

As the first step in my community analysis, I completed a Detrended Correspondence Analysis (DCA) to determine the length of axis gradient and distribution of data for the pairs and broods. These analyses indicated relatively long

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gradient lengths (> 2 standard deviations) indicative of unimodal distributions of data. As a result, I used Reciprocal Averaging (RA) to complete the analysis of both pair and brood data in the Buffalo Lake Moraine (ter Braak 1987). All ordinations were completed with PC-Ord (version 4.0, MjM Software, Gleneden Beach, Oregon).

A joint plot was used to represent graphically the relationship between ordination scores (e.g. species scores and/or site scores) and environmental variables (McCune and Melford 1999). Using environmental data collected through both field collection and the use of GIS, joint plots were created for both pairs and broods with select environmental variables. Only environmental variables with r^2*-values,* >0.05 were used to create species scores-environmental joint plots (McCune and Mefford 1999). Joint plots have lines or vectors radiating out from the centroid of the ordination with both the direction and angle of joint plot vectors providing meaningful interpretation with regards to environmental variable and location of species scores. However, the relative length of the joint plot vectors is arbitrary. PC-Ord (version 4.0, MjM Software, Gleneden Beach, Oregon) was used to create the joint plots and graphically represent the results.

With the implementation of a nest box program, the breeding densities of both Common Goldeneye and Bufflehead have increased within the study area, while densities of other waterfowl and waterbird species have remained stable or decreased (Chapter 2). To examine the potential impacts of increased densities of Common Goldeneye on community structure of both pairs and broods in the Buffalo Lake Moraine, I compared the similarities of community composition for wetlands before and after the provision of nest boxes in the Buffalo Lake Moraine (Chapter 2). Using both a Mantel test (Mantel 1967) and PROTEST (Jackson 1995), I compared concordance between community composition based on waterfowl and waterbird pairs and broods between 1989 and 2003, i.e. years in which densities of Common Goldeneye and Bufflehead were low and high, respectively. Community structure was evaluated for ordinations both with Common Goldeneye and Bufflehead included in the community analysis and with the 2 species removed from analysis. Common

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Goldeneye and Bufflehead were removed to ensure the comparison of concordance was reflective of overall community composition and not driven by increased abundance of these 2 species.

Specifically, I tested for a statistically significant relationship between matrices that defined community structure collected in 1989 (i.e. when densities of Common Goldeneye and Bufflehead were low) with that collected in 2003 (i.e. when densities of Common Goldeneye and Bufflehead were high). Mantel tests estimate the association between species occurrence data from the same sampling location (i.e. wetlands) and returns an estimate of a linear relationship (Fortin et. al 2002). Because the relationship is based on a chosen distance measure and not site data, the intensity of the relationship (i.e. Mantel r coefficient) is of less importance compared to whether the 2 matrices are significantly ($p<0.05$) related (Fortin *et al.* 2002). Further descriptions of the Mantel test are offered in Legrende and Legrende (1998) and Urban et. al (2002).

Jackson (1995) developed a method of testing for concordance based on permutations procedures using a Procrustean matrix. This permutation procedure is called PROTEST and can be used to test for statistical significance of Procrustean fit, while comparing the level of association between 2 matrices. Peres-Nesto and Jackson (2001) suggested that PROTEST was a more powerful analysis compared to the Mantel test, because analyses are based on actual data (or ordination scores) compared to the analyses based on distance measures of the Mantel test. Dutilleul et al. (2000) found that results are not necessarily consistent between the two tests; therefore I performed both the Mantel test and PROTEST when testing for concordance between community structure in 1989 and 2003. Analysis of concordance was based on wetlands that had a least 1 pair (n=498) and at least 1 brood (n=96), during both 1989 and 2003.

Additional analysis of concordance was completed on wetlands without the presence of Common Goldeneye and/or Bufflehead and had least 1 pair (n=412) and

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at least 1 brood (n=89), during both 1989 and 2003. Both the Mantel test and PROTEST evaluate the null hypothesis that there is no similarity in relationships of community structure between the 2 time periods and were completed using Monte Carlo randomizations (Mantel test, n=1000 permutations and PROTEST n=9999 permutations). The Mantel test was performed using a Sorenson distance measure, which is recommended for the analysis of presence/absence data (McCune and Mefford 1999). Both forms of concordance testing were performed using matrices composed of raw data.

Behavioral observations and intra-specific and inter-specific interaction

In 2004, using focal animal sampling, I estimated the time budgets for territorial Common Goldeneye and Bufflehead drakes in the Buffalo Lake Moraine during 42 hours of observation between 11 May and 3 June 2004 (Common Goldeneye n=26 hours, Bufflehead n=16 hours). Observations were made on a subset (n=8, for Common Goldeneye, n= 5, for Bufflehead) of wetlands within the BLM study area. All observations involved unmarked birds, therefore there were no provisions to ensure multiple observations did not occur on the same focal animal. To reduce the likelihood of pseudo-replication, observations occurred at different wetlands throughout the Buffalo Lake Moraine study area. Observations occurred on at least 2 different dates and observation periods lasted either 60 minutes or 120 minutes. At the beginning of all observation periods and at 15-minute intervals, the abundance of waterfowl and waterbird species were recorded. At 2-minute intervals, focal animals were observed to determine the dominant activity throughout a 10-second interval. The dominant activity was recorded as: feeding, resting, preening, aggression and non-aggressive display.

Incidental aggressive interactions solely involving focal *Bucephala spp.* were also recorded. Aggressive interactions and behaviors included; threats, attacks and fights as described by Eadie *et. al* (1995) for Common Goldeneye and Gauthier (1993) for Bufflehead. Only 1 interaction per continuous contact was recorded, with

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highest level of aggression being used for analysis. For example, if a threat progressed to an attack, then only the attack was recorded. Aggressive episodes were typically initiated when intruding waterfowl entered into areas defended by either Common Goldeneye or Bufflehead and concluded when the intruder left the defended area. During each aggressive episode, the species and sex of both the aggressor and the recipient of aggression were recorded.

I assessed differences in the rate of intra and inter-specific aggressive interactions involving both *Bucephala spp.* and other waterfowl using a Wilcoxon rank-sum test (Gould and Gould 2002). I calculated the mean (± S.E) aggression rates (number of interactions/hr) for each wetland and subsequently calculated the overall mean (± S.E) for intra and inter-specific aggression rates across all wetlands. I also compared intra and inter-specific aggression rates between Common Goldeneye and Bufflehead as well as inter-specific of aggressive rates between *Bucephala spp.* and diving ducks (Canvasback (*Athya valisineria)*, Redhead (*Athya americana)*, Ring-necked Duck *(Aythya valisineria)*, Hooded Merganser (*Lophodytes cucullatus)* and Lesser Scaup (*Athya affinis)*) and dabbling ducks (Mallard (*Anas platyryhnchos),* Blue-winged teal (*Anas discors)*, Green-winged Teal (*Anas crecca*) and Gadwall (*Anas strepera*)).

Results

<u>Occurrence of waterfowl and waterbirds</u>

<u>Pairs</u>

A list of all waterfowl and waterbird species included in the analysis of pair data and the frequency of occurrence is found in Appendix 3.3. Mallard, Gadwall and Blue-wing teal and to a lesser extent, American Wigeon, Northern Shoveler, Redhead and Lesser Scaup were the most frequently occurring species in the Buffalo Lake Moraine (Appendix 3.3). The frequency of occurrence of waterfowl and waterbird pairs on study area wetlands between 1989 and 2003 suggests differences

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between dabblers, divers and waterbirds. All species of dabblers, decreased in frequency from 1989 to 2003, with Mallard, Gadwall and Blue-wing teal occurring with the greatest frequency in both study years (Appendix 3.3). Four species of diving ducks, Redhead, Common Goldeneye, Bufflehead and Ruddy Duck were more frequently encountered in 2003 compared to 1989, whereas Canvasback and Lesser Scaup were encountered less frequently in 2003 than in 1989 (Appendix 3.3). American Coot increased in occurrence frequency whereas Red-neck Grebe and Horned Grebe occurred less frequently in 2003 compared to 1989 (Appendix 3.3). In contrast to many species, the occurrence of Common Goldeneye and Bufflehead and presence of broods for both of these species increased substantially between 1989 and 2003.

Broods

Similar to the occurrence of pairs, broods produced by Mallards and Blue-winged Teal were also most frequently encountered. However, the frequency of broods occurring on study area wetlands showed some interesting contrasts to the frequency of pairs. Whereas, the occurrence of pairs for all species of dabbling ducks decreased in frequency (Appendix 3.3), the frequency of dabbling duck broods actually increased for Mallard, Gadwall, Green-wing Teal, Blue-wing Teal and Northern Shoveler (Appendix 3.3). Redhead, Common Goldeneye and Bufflehead broods all increased in frequency in 2003, whereas Canvasback and Lesser Scaup broods were present on fewer wetlands in 2003. Broods of both *Podiceps spp.* occurred less frequently in 2003 compared to 1989, whereas the occurrence of American Coot increased (Appendix 3.3).

The relationship between the presence of broods and pairs was generally stronger for divers and waterbird when compared to dabblers (Table 3.4). In both 1989 and 2003 the presence of broods was not independent of the occurrence of pairs for Bufflehead, Ruddy Duck, Horned Grebe and American Coot. Lesser Scaup (1989) and Common Goldeneye (2003) also demonstrated significant relationships

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between the presence of pairs and the occurrence of broods but only in 1 study year. The non-significant relationship observed by Common Goldeneye in 1989 and Lesser Scaup in 2003 may be due to low number of broods observed for these species in respective years. In both 1989 and 2003, no species of dabbling ducks demonstrated a significant relationship between the occurrence of pairs and broods.

Table 3.4: Relationship of the presence of broods in wetlands with presence of pairs in study area wetlands in 1989 and 2003 for select waterfowl and waterbird species. Only waterfowl and waterbird species which were included in both the pairs and broods ordination were included in this analysis. Only wetlands (n=438) that had the presence of pair(s) and/or brood(s) in both years were included in analysis. Evaluation of the hypothesis of independence between the presence of pairs and broods was conducted using a 2 x 2 contingency table and analyzed with a Fisher Exact test. Species with $p<0.05$ reject hypothesis of independence and conclude that the presence of pairs and broods are dependent, i.e. Presence of a pair during spring pair surveys was a good predictor for the presence of a brood in later summer surveys.

Species	1989 Probability	2003 Probability
Mallard	P= 0.54	P= 0.12
Gadwall	P= 0.25	P= 0.14
Blue-wing Teal	P= 0.18	P= 0.12
American Wigeon	P= 0.27	P= 0.70
Northern Shoveler	P= 0.11	P= 0.23
Northern Pintail	P=0.05	P=0.94
Redhead	P=0.20	P=0.07
Canvasback	P= 0.22	P= 0.23
Lesser Scaup	**P= 0.01**	P= 0.29
Common Goldeneye	P= 0.08	**P= <0.01**
Bufflehead	**P= 0.01**	**P= <0.01**
Ruddy Duck	**P= <0.01**	**P= 0.01**
American Coot	**P= <0.01**	**P= <0.01**
Horned Grebe	**P= <0.01**	**P= <0.01**

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General relationships between community structure and environmental variables

Pairs

Results, site scores and species scores of the waterfowl and waterbird pair RA ordination and environmental joint plots are summarized in Appendices 3.4, 3.5, 3.6 and 3.7 and presented in Figures 3.2, 3.3, 3.4 and 3.5. The RA illustrates differences between communities in the BLM study area, generally separating species by foraging guilds (Figure 3.3). In both years the majority of dabblers had negative species scores on axis 1, with Mallard in 1989 and Pintail in 2003 being the only exceptions. In 1989, all species of divers and waterbirds had positive species scores on axis 1. Interestingly, in 2003, Common Goldeneye and Bufflehead had negative species scores on axis 1 while all other species of divers and waterbirds had positive scores on the same axis.

In 1989 and 2003, Common Goldeneye and Bufflehead species scores for axis 2 were noticeably different than all other species of divers and waterbirds. In 1989, both Common Goldeneye and Bufflehead had positive species scores for axis 2, while all other divers and waterbirds had negative species scores for this same Axis (Figure 3.3, Appendix 3.4). The difference between species scores for Common Goldeneye and Bufflehead on axis 2, versus other divers and waterbirds, was also evident in 2003 (Figure 3.3, Appendix 3.5). Results of the 1989 and 2003 pair ordinations indicate that Common Goldeneye and Bufflehead species scores were distinct from all other species of waterfowl and waterbirds. When the RA ordinations were completed without the presence of Common Goldeneye and Bufflehead, divers and waterbirds were clustered separately from dabblers along axis 1 (Figure 3.5).

Correlation coefficients of environmental variables and pair ordination species scores can be found in Appendix 3.4, 3.5, 3.6 and 3.7 and are presented as joint plots in Figures 3.3 and 3.5. For all RA ordinations completed for pairs, water level was consistently one of the most important environmental variables, particularly showing a strong positive correlation with axis 2. Although not as strong, wetland type was also an important environmental variable, being positively correlated with axis 1 in

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both years. In both 1989 and 2003, wooded uplands was identified an important factor in determining the position of Common Goldeneye and Bufflehead along both axis 1 and 2. When these 2 species were removed from the ordinations, the importance of wooded uplands was diminished (Appendix 3.6 and 3.7). For 2003, Easting was identified as the most significant environmental variable associated with axis 1, but was only marginally significant in 1989. Similarly, water level and wetland type were also more important in 2003 than in compared to 1989. The importance of Easting, water level and wetland type in 2003, compared to 1989 may be reflective of drought conditions experienced in the Buffalo Lake Moraine during the 2003 breeding season and the different wetland types associated with and East – West gradient within the study area.

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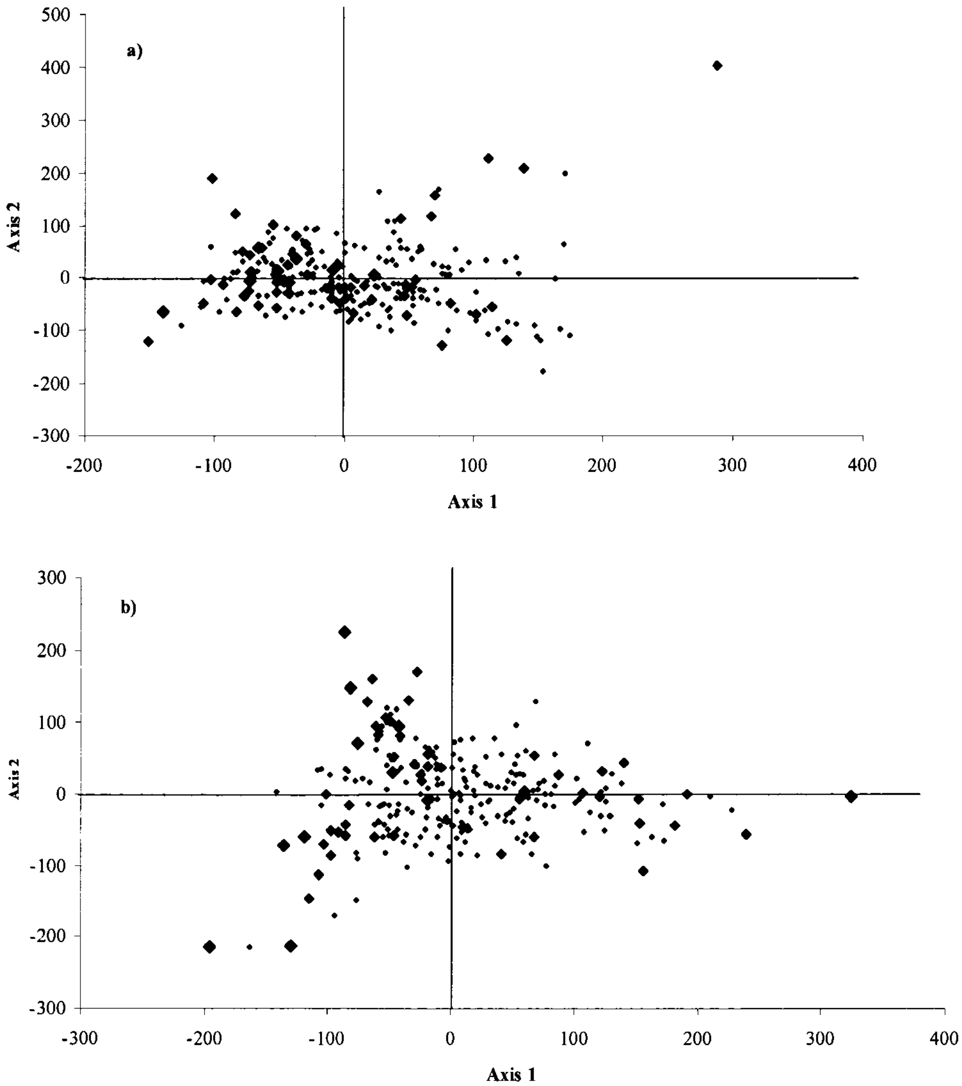

Figure 3.2: Ordination based on results of Reciprocal Averaging (RA) for 498 wetlands based on the presence/absence of waterfowl and waterbird pairs in the Buffalo Lake Moraine for a) 1989 and b) 2003. ♦=1 site, ♦=2- 4 sites, ♦ = >5 sites.

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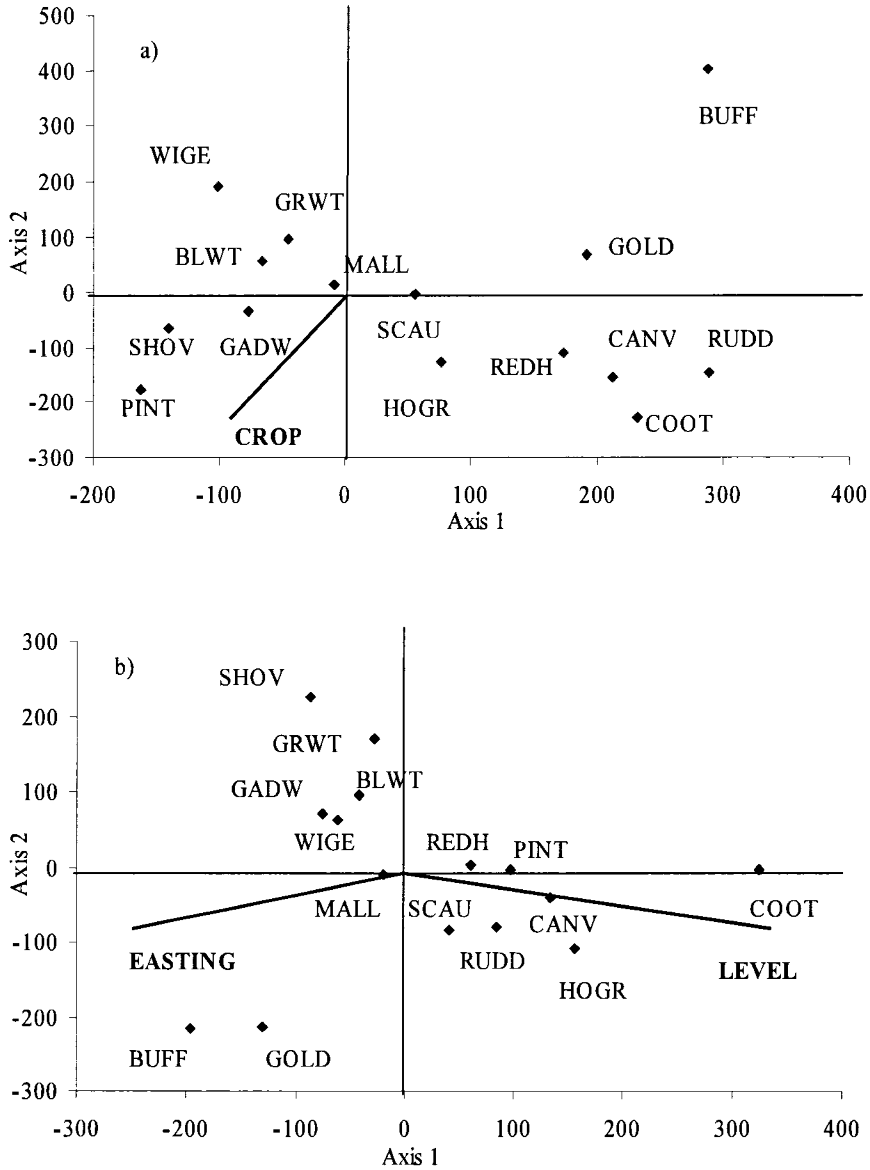

Figure 3.3: Joint plot of Reciprocal Averaging (RA) ordination of waterfowl and waterbird pair species scores and environmental variables (r^2>0.05) for wetland sites (n=498) in the Buffalo Lake Moraine for a) 1989 and b) 2003.

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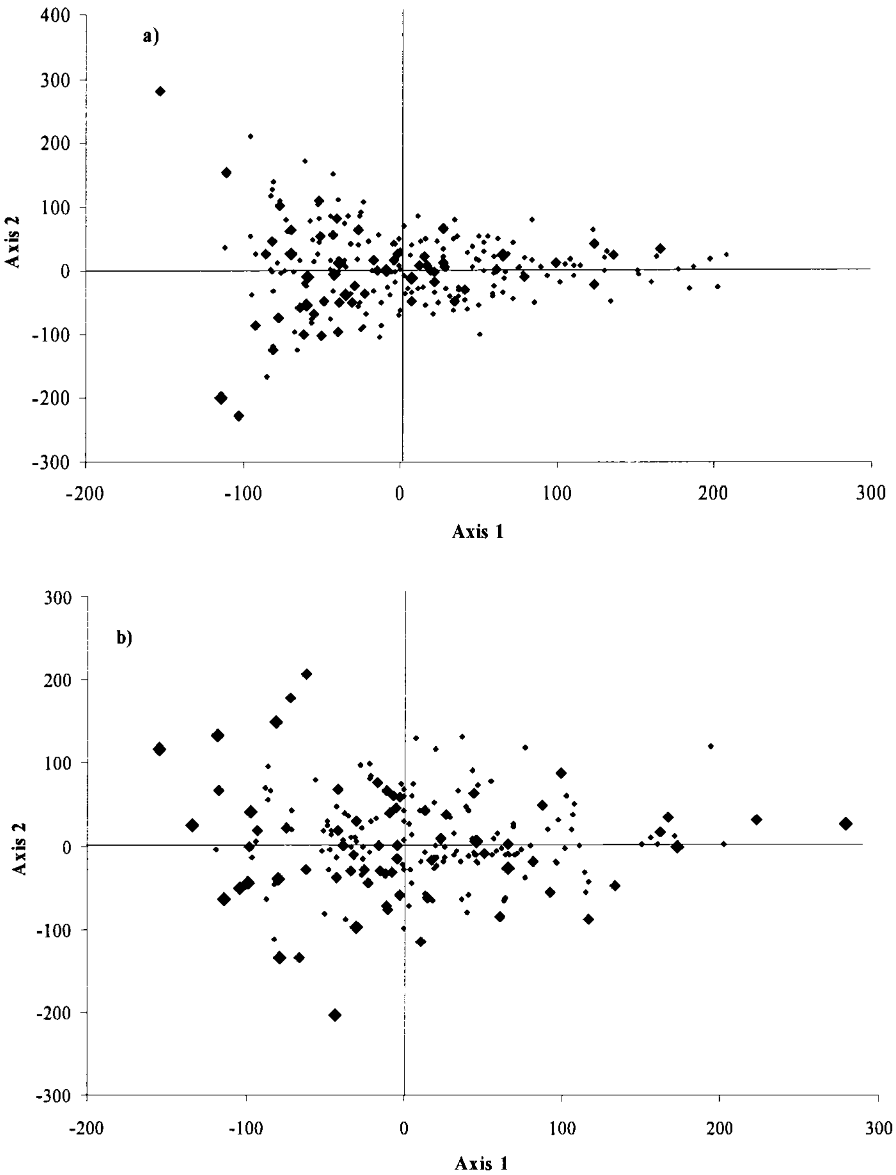

Figure 3.4: Ordination based on results of Reciprocal Averaging (RA) for 412 wetlands based on the presence/absence of waterfowl and waterbird pairs in the Buffalo Lake Moraine for a) 1989 and b) 2003. Common Goldeneye and Bufflehead were removed from ordination and treated as environmental variables. ♦=1 site, ♦=2- 4 sites, ♦ = >5 sites.

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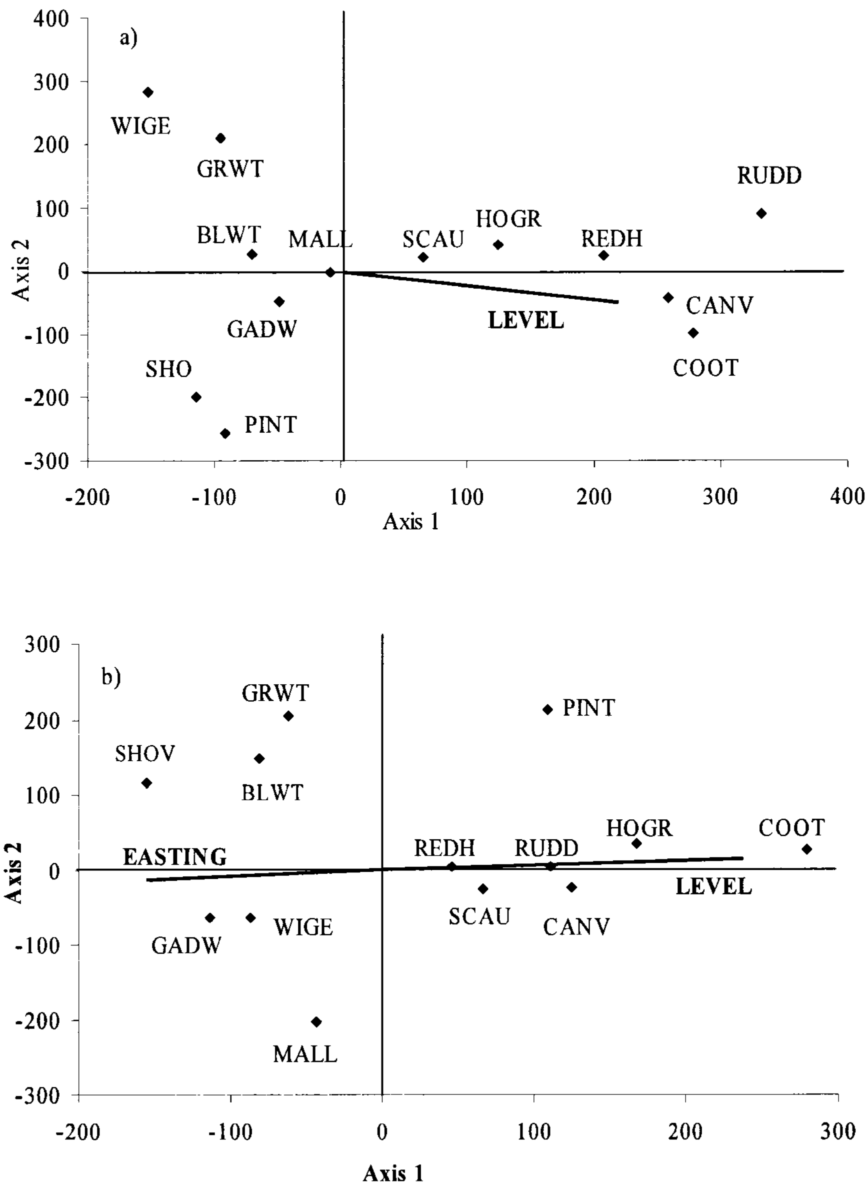

Figure 3.5: Joint plot of Reciprocal Averaging (RA) ordination for waterfowl and waterbird pair species scores and environmental variables (r^2>0.05) for wetland sites (n=412) in the Buffalo Lake Moraine for a) 1989 and b) 2003. Common Goldeneye and Bufflehead were removed from ordination and treated as environmental variables.

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Broods

Results of the waterfowl and waterbird brood RA ordination and environmental joint plot are summarized in Appendix 3.8, 3.9, 3.10 and 3.11 and presented in Figures 3.6, 3.7, 3.8 and 3.9. In 1989, brood ordinations did not result in separation of waterfowl and waterbird along feeding guilds to the same extent as the pair ordination. The 1989 brood ordination was likely confounded by the distribution of Canvasback, reflected by species scores associated with axis 1 (Figure 3.7). Canvasback were present in very few brood ponds in 1989 (8.08 %; Appendix 3.3) and in fact, three of the ponds with Canvasback broods, had no other species present (Figure 3.7). As a result, Canvasback scores strongly affected the overall 1989 brood ordination, particularly along axis 1. When Common Goldeneye and Bufflehead were removed from the 1989 brood ordinations, community patterns were not altered to any noticeable degree.

Generally, results of the 2003 ordinations reflected separation of species scores among foraging guilds, similar to the pair ordinations. All species scores for divers were positive on axis 1, however American Coot, Horned Grebe and Red-necked Grebe species scores were negative, thus patterns differed from pair ordination results. In 2003, Canvasback, Lesser Scaup, Redhead and Ruddy Duck species scores were all very similar, with both Common Goldeneye and Bufflehead species scores being visibly different from other species of diving ducks (Figure 3.7). When Common Goldeneye and Bufflehead were removed from the 2003 brood ordination, community patterns did not change to any large degree (Figure 3.9). Canvasback, Redhead, Lesser Scaup and Ruddy Duck species scores remained closely clustered and became further separated from dabbling duck species.

For brood ordinations that included all species, both water level and Easting were significantly correlated with species scores in both 1989 and 2003 (Figure 3.7; Appendix 3.8 and 3.9). As discussed earlier, both water level and Easting were identified as significant environmental variables in the pair ordinations and these 2

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factors remain important factors for broods as well. Additionally, wooded uplands and Northing were identified as important environmental variables both years for brood ordinations. In 2003, wooded upland cover (r=0.35; axis 2) had the highest correlation coefficient of any environmental variable for any ordination completed. Not surprisingly, wooded uplands were strongly associated with the presence of Common Goldeneye broods. In both years, water level was strongly correlated with the presence of American Coot. In contrast to the pair ordination, water level was not strongly correlated with the presence of divers, particularly in 2003, when all species of divers had positive scores on axis 1, while water level was negatively correlated with the same axis. Similar to the pairs, Easting was a significant variable for the brood ordination; however, there was little relationship between Easting and specific feeding guilds. When Common Goldeneye and Bufflehead were removed from the brood ordination, few environmental variables remained significant. Again water level and Easting remained significant for both the 1989 and 2003 ordinations and the presence of Bufflehead was considered a significant environmental variable for broods in 2003 and was highly correlated with axis 2 (Figure 3.9).

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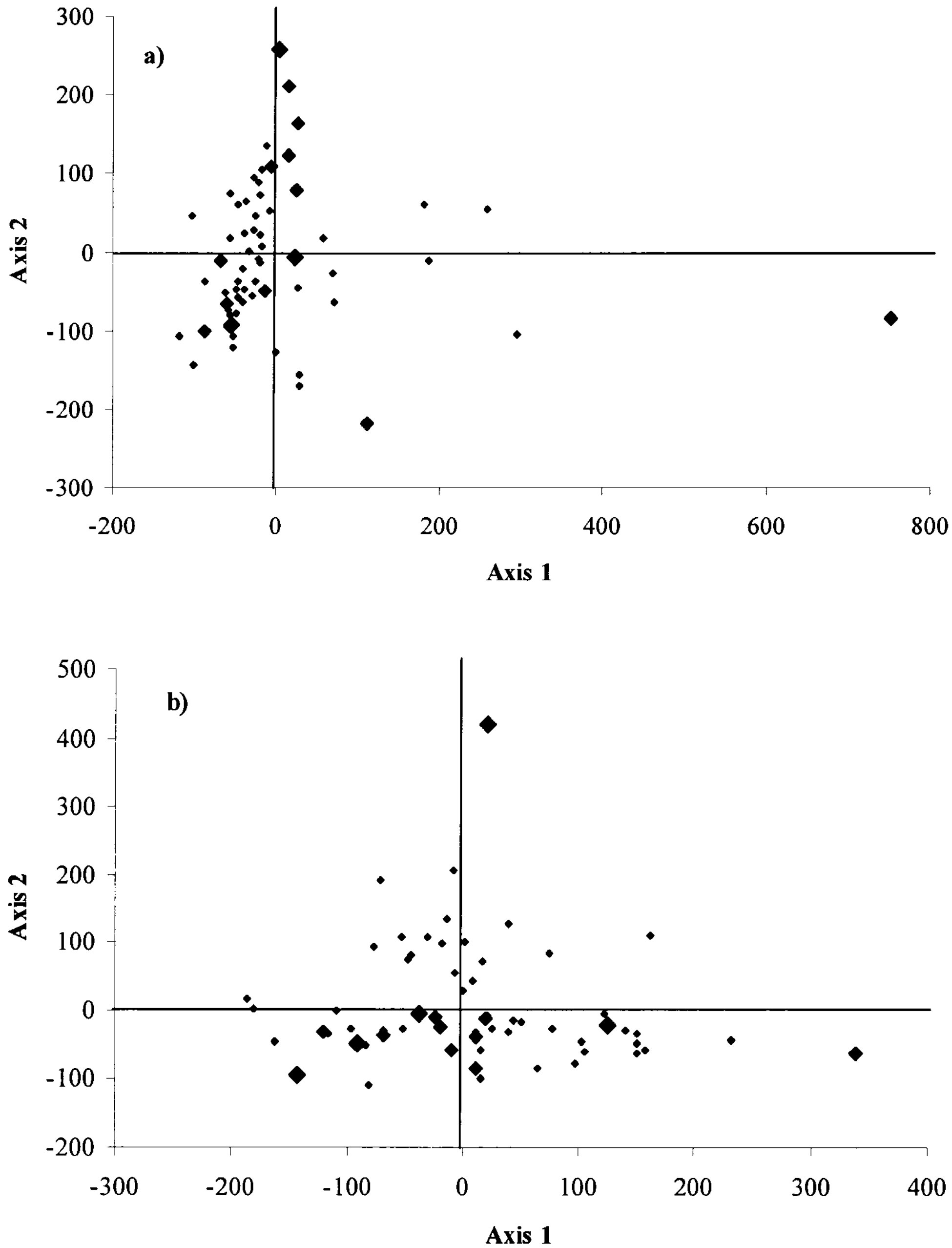

Figure 3.6: Ordination based on results of Reciprocal Averaging (RA) for 96 wetlands based on the presence/absence of waterfowl and waterbird broods in the Buffalo Lake Moraine for a) 1989 and b) 2003. ♦=1 site, ♦=2- 4 sites, ♦ = >5 sites.

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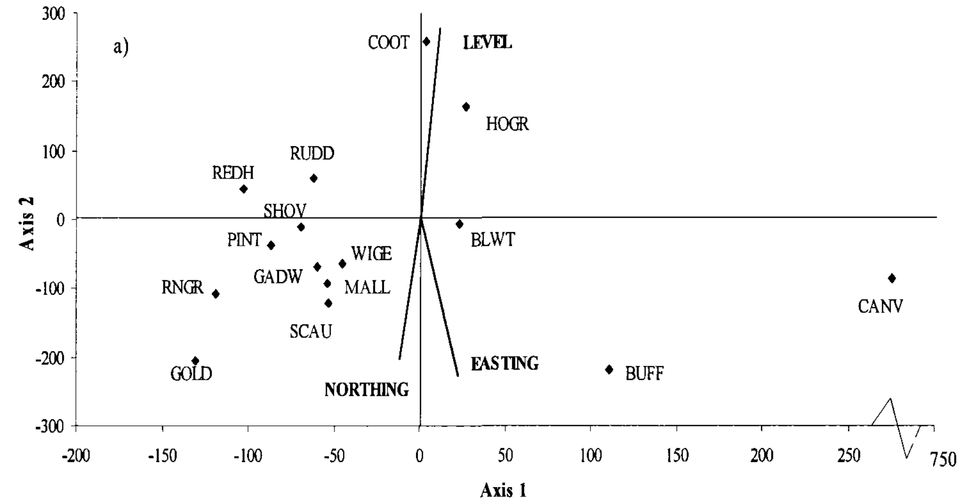

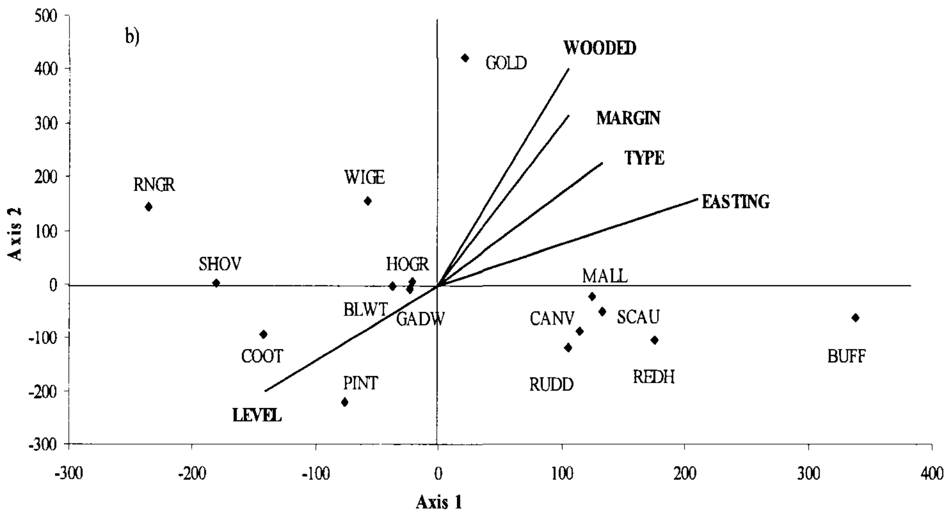

Figure 3.7: Joint plot of Reciprocal Averaging (RA) ordination for waterfowl and waterbird brood species scores and environmental variables ($r^2>0.05$) for wetlands (n=96) in the Buffalo Lake Moraine for a) 1989 and b) 2003.

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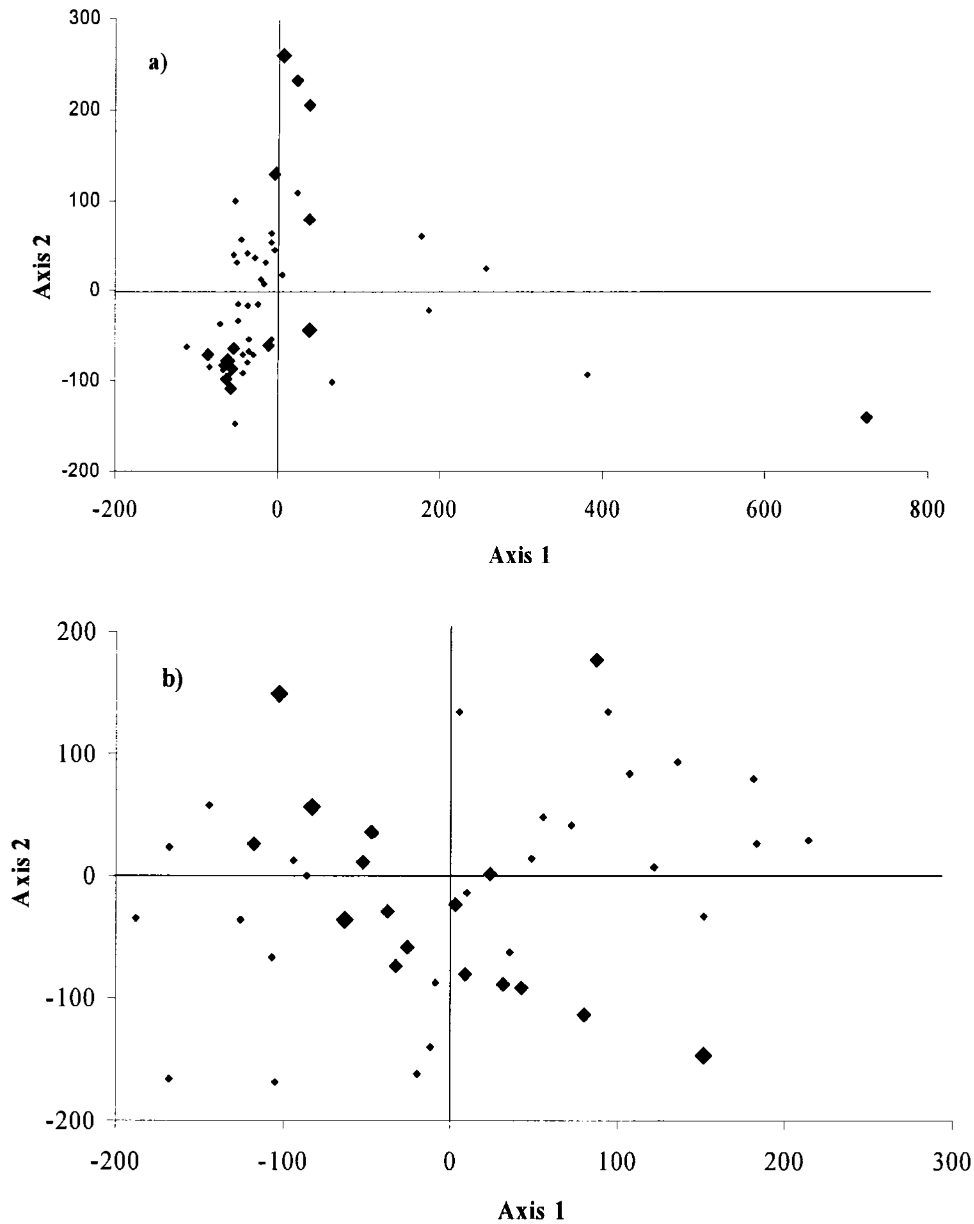

Figure 3.8: Ordination based on results of Reciprocal Averaging (RA) for 89 wetlands based on the presence/absence of waterfowl and waterbird pairs in the Buffalo Lake Moraine for a) 1989 and b) 2003. Common Goldeneye and Bufflehead were removed from ordination and treated as environmental variables. ♦=1 site, ♦=2-4 sites, ♦ = >5 sites.

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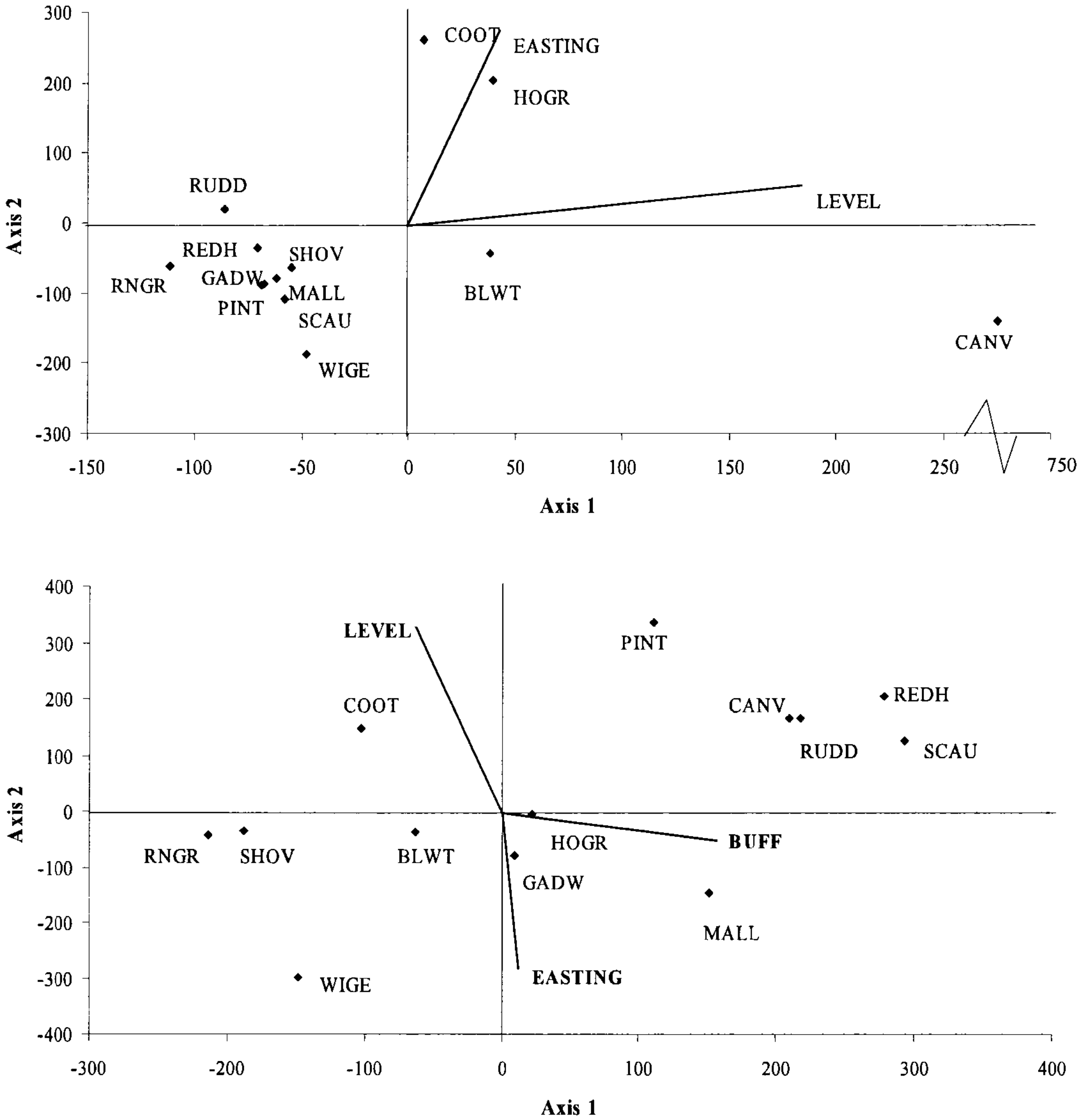

Figure 3.9: Joint plot of Reciprocal Averaging (RA) ordination of waterfowl and waterbird brood species scores and environmental variables (r^2>0.05) for wetlands (n=89) in the Buffalo Lake Moraine for a) 1989 and b) 2003. Common Goldeneye and Bufflehead were removed from ordination and treated as environmental variables.

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Evaluating the effects of Common Goldeneye and Bufflehead on community structure

I tested for effects of increased densities of Common Goldeneye and Bufflehead on waterfowl and waterbird communities by comparing concordance of bird communities in 1989, when densities were low and in 2003, when densities were high. Using matrices obtained from the presence/absence data, I tested for community concordance both with Common Goldeneye and Bufflehead included in the analysis and with these 2 species removed from the analysis. Results of both the Mantel tests and the PROTEST method rejected the null hypothesis of no similarity between the two time periods, at $P<0.10$. This result was observed using data describing the presence of pairs with all species included in the analysis (Mantel test: $p=0.005$, PROTEST: $p<0.001$) and when Common Goldeneye and Bufflehead were removed (Mantel test: $p=0.002$, PROTEST: $p<0.001$). Concordance between time periods was also observed when wetlands were analyzed for the presence of broods with all species included in the analysis (Mantel test: $p=0.04$, PROTEST: $p=0.07$) and when Common Goldeneye and Bufflehead were removed (Mantel test: $p=0.02$, PROTEST: $p=0.04$). These data suggest that the composition of aquatic bird communities on wetlands within the Buffalo Lake Moraine did not differ with low versus high *Bucephala spp.* densities.

Behavioral Observations and Intra and Inter-specific aggression

Territorial drake Common Goldeneye and Bufflehead allocated the majority of time during egg-laying and early-incubation periods to resting (which included swimming and sleeping), followed by feeding and preening (Figure 3.10). Combined, these 3 activities accounted for >80% of the estimated time budget for both species. Both species allocated a low percent of time to aggressive behaviors (i.e. threat, attack and fight), (Common Goldeneye = 12.5% and Bufflehead =10%) and to display (Common Goldeneye =7% and Bufflehead =4%). Lastly, Common Goldeneye and Bufflehead allocated similar proportions of time to each of the 5 activity types (Figure 3.10).

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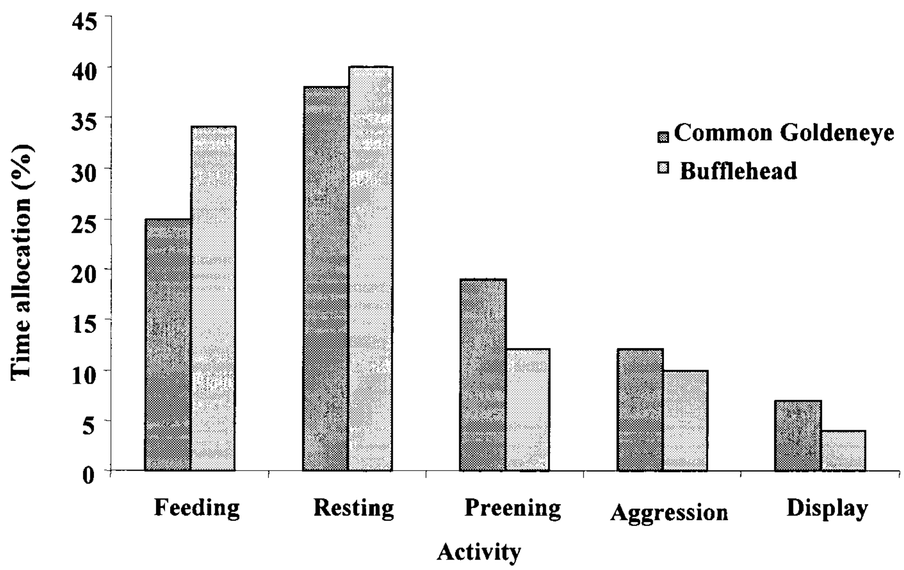

Figure 3.10: Estimated time budget for Common Goldeneye and Bufflehead territorial drakes in the Buffalo Lake Moraine of central Alberta. Data were collected using focal animal sampling of Common Goldeneye (n=26 hours) and Bufflehead (n=16 hours) drakes during May and June 2004.

Intra and inter-specific aggression

Aggression towards congeners accounted for 84.6% (Common Goldeneye) and 75.8% (Bufflehead) of all aggressive interactions (Table 3.5). For both *Bucephala spp.*, aggression toward conspecific individuals occurred more commonly than aggression directed towards individuals of other species (Table 3.5). Of all aggressive interactions initiated by Common Goldeneye, 43.6% (i.e. 51 of 117 interactions) of the contacts were directed at conspecifics; similarly, 49.5% (45 out of 91 interactions) of interactions instigated by Bufflehead were directed towards conspecifics (Table 3.5). Inter-specific aggression by both *Bucephala spp.* was predominantly directed towards congeners, specifically, 72.7% inter-specific aggression initiated by Common Goldeneye was directed towards Bufflehead and 52.2% of inter-specific aggression instigated by Bufflehead was directed towards Common Goldeneye (Table 3.5).

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Inter-specific aggression initiated by Common Goldeneye involved interactions with 8 different species of waterfowl, whereas inter-specific aggression instigated by Bufflehead involved 6 species of waterfowl (Table 3.5). Both *Bucephala spp.* more frequently instigated aggression towards divers rather than dabblers (Table 3.5). The abundance of dabbling ducks on wetlands where Common Goldeneye focal sampling occurred was almost 3 times greater than the abundance of dabbling ducks on these same wetlands (Table 3.6). Similarly, the abundance of dabbling ducks on Bufflehead focal sampling wetlands was almost double the abundance of divers on the same wetlands (Table 3.7). Despite being less abundant than dabbling ducks, diving duck species were more likely to be recipients of aggression initiated by both Common Goldeneye and Bufflehead.

Table 3.5: Percent of observed incidents of inter-specific and intra-specific aggression (n=208) involving territorial Common Goldeneye and Bufflehead drakes in the Buffalo Lake Moraine. Data are based on 26 hours of behavioral observations of Common Goldeneye and 16 hours of Bufflehead during May and June 2004.

	Aggressor	
Recipient	**Common Goldeneye**	**Bufflehead**
Common Goldeneye	43.6	26.4
Bufflehead	41.0	49.5
Redhead	0.9	13.2
Lesser Scaup	7.8	2.2
Canvasback	0	6.6
Ring-neck Duck	0.9	0
Hooded Merganser	0.9	0
Gadwall	2.6	1.1
Mallard	0	1.1
Blue-winged Teal	1.7	0
Green-winged Teal	0.9	0
Number of incidents	*117*	*91*

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Table 3.6: Mean number of Common Goldeneye (COGO), Bufflehead (BUFF), diving ducks (Divers) and dabbling ducks (Dabblers) on study area wetlands during focal animal sampling of Common Goldeneye in the Buffalo Lake Moraine during 2004. The occurrence of waterfowl was recorded at the initiation and conclusion of sampling period.

Wetland	COGO	BUFF	Divers	Dabblers
1-1	6.67	3.17	7.67	11.00
2-176	1.67	1.11	1.56	11.00
4-95	9.00	6.33	3.50	16.17
5-85	1.75	2.00	1.75	1.50
5-86	3.33	3.78	1.56	5.78
5-217	2.50	1.00	3.50	4.69
6-159	1.57	3.29	5.29	7.86
Chimney	4.83	3.00	8.33	10.67
Mean (± SE)	3.84 (± 0.49)	3.02 (±0.35)	3.98 (± 0.59)	9.94 (± 0.94)

Table 3.7: Mean number of Bufflehead (BUFF), Common Goldeneye (COGO), diving ducks (Divers) and dabbling ducks (Dabblers) on study area wetlands during focal animal sampling of Bufflehead in the Buffalo Lake Moraine during 2004. The occurrence of waterfowl was recorded at the initiation and conclusion of sampling period.

Wetland	BUFF	COGO	Divers	Dabblers
4-95	3.50	3.25	4.75	14.00
5-85	6.88	1.75	6.25	6.63
5-86	3.20	1.20	1.00	3.60
5-217	1.75	2.25	5.75	23.25
6-159	4.25	1.50	13.00	9.75
4-95	3.50	3.25	4.75	14.00
5-85	6.88	1.75	6.25	6.63
5-86	3.20	1.20	1.00	3.60
Mean (± SE)	4.36 (± 0.49)	1.92 (± 0.23)	5.96 (± 0.91)	9.28 (± 0.22)

Patterns of intra versus inter-specific aggression rates showed similarities between the 2 *Bucephala spp.* The rate at which territorial Common Goldeneye males initiated aggressive interactions towards conspecifics versus toward Bufflehead did not differ significantly ($p>0.05$) (Table 3.8). Likewise, Bufflehead intra-specific aggression rates were not significantly different from aggression rates directed towards Common Goldeneye ($p>0.05$; Table 3.9). In 6 out of the 8 study area

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wetlands where Common Goldeneye observations occurred, there was inter-specific aggression involving Common Goldeneye as the aggressor towards non-congeners. Inter-specific aggression initiated by Bufflehead involving non-congeners occurred on all 5 wetlands where focal sampling occurred. These results indicate a modest level of inter-specific interactions initiated by *Bucephala spp.*

Table 3.8: Rate of intra and inter-specific aggression by Common Goldeneye on 8 wetlands within the Buffalo Lake Moraine study area during 2004. Values for each wetland represent the mean number of aggressive interactions per hour of observation. Probability reflects a null hypothesis that there is no difference between the rates of intra and inter-specific aggression, calculated using a Wilcoxon rank-sum test.

		Recipient of Aggression		
Wetland	**COGO**	**BUFF**	**Divers**	**Dabblers**
1-1	3.33	1.00	3.00	0.33
2-176	0.60	3.40	0.20	0.00
4-95	4.67	0.67	0.33	0.00
5-85	1.00	0.00	0.00	0.00
5-86	1.60	4.00	0.20	0.00
5-217	3.00	0.00	0.00	1.50
6-159	1.33	1.00	0.00	0.67
Chimney	1.33	1.00	0.00	0.00
Mean (± SE)	2.11 (± 0.50)	1.38 (±0.53)	0.47 (± 0.37)	0.31 (± 0.19)
Probability		0.33	0.01	0.01

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Table 3.9: Incidents of intra and inter-specific aggression by Bufflehead on 5 wetlands within the Buffalo Lake Moraine study area during 2004. Values for each wetland represent the mean number of aggressive interactions per hour of observation. Probability reflects a null hypothesis that there is no difference between the rates of intra and inter-specific aggression, calculated using a Wilcoxon rank-sum test.

	Recipient of Aggression			
Wetland	**COGO**	**BUFF**	**Divers**	**Dabblers**
4-95	2.67	1.33	1.00	0.00
5-85	1.40	0.20	2.20	0.40
5-86	5.00	1.00	0.33	0.00
5-217	0.00	4.50	1.50	0.00
6-159	5.00	2.33	0.67	0.00
Mean (± SE)	2.81 (± 0.99)	1.87 (± 0.74)	1.14 (± 0.33)	.08 (± 0.08)
Probability		0.67	0.23	0.07

Although diving ducks were less abundant, both Common Goldeneye and Bufflehead were more likely to initiate aggressive interactions against diving ducks than dabblers (Table 3.8 and 3.9). The rate at which Common Goldeneye interacted aggressively with both divers and dabblers differed significantly (Wilcoxon Rank-sum test p=<0.05) from both the intra-specific aggression rates and the inter-specific aggression rate with Bufflehead (Table 3.8). Of the 12 total aggressive incidents involving Common Goldeneye and divers, 9 of these occurred on 1 wetland. Similar to Common Goldeneye, Bufflehead aggression rates were also higher with divers compared to dabbling ducks (Table 3.9). Aggression initiated by Bufflehead and directed towards diving ducks did not differ significantly (p>0.05) from the observed rates between divers and Common Goldeneye. Aggression between Bufflehead and diving ducks occurred on all 5 wetlands where observations occurred, whereas aggression towards dabblers only occurred on only 1 of these wetlands.

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DISCUSSION

Analysis of aquatic bird community structure in the Buffalo Lake Moraine generally revealed comparable habitat relationships for species within foraging guilds. Between 1989 and 2003, the frequency of occurrence for all species of dabbling ducks decreased, while 5 species of diving ducks increased during this period (Appendix 3.2). The relationship between the presence of broods in wetlands and the presence of pairs in the same wetlands was also distinctly different between divers and dabblers. Generally there was a very strong relationship for diving ducks and waterbirds between the presence of pairs and broods compared to a much weaker relationship for dabbling ducks (Table 3.4). Two mechanisms may be responsible for the difference in the relationship strength for the presence of pairs and broods between the two foraging guilds. Generally, dabbling ducks are more likely to move broods overland to multiple wetlands prior to fledging compared to diving ducks. Additionally, the ability for observers to locate broods is quite low, especially for dabbling ducks (Cowardin and Blohm 1992). Thus, the weaker relationship between the presence of dabbling duck pairs and broods likely reflects movement of dabbling duck broods between wetlands and the ability to locate visually dabbling duck broods during standard surveys.

Similar patterns of assemblages composed of bird species with similar feeding strategies were particularly evident with ordinations performed for aquatic bird pairs in 1989. In 1989, all species of diving ducks, as well as Horned Grebe and American Coot were positively associated with axis 1, whereas, with the exception of Mallard, all species of dabblers were negatively associated with axis 1 of the RA (Figure 3.3). The same general pattern exists in the 2003 ordination, with the majority of diving ducks positively associated with axis 1. There were 2 notable exceptions; both Common Goldeneye and Bufflehead were negatively associated with axis 1 in 2003, clearly distinct from all other species of diving ducks and waterbirds. The presence of these two species in 1989 was as yet unaffected by the deployment of nest boxes, therefore the occurrence on area wetlands likely reflects natural cavity availability.

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However, by 2003, the distribution of Common Goldeneye and Bufflehead was affected by increased availability and the use on nest boxes for nesting.

In the 1989 pair ordinations, wetland type, water level, perimeter and proportion of wetlands were all important environmental variables, which characterized wetlands associated with bird species along axis 1. Again in 2003, wetland type and water level were important environmental variables influencing bird species along axis 1. In both years, water level was an important environmental variable for the occurrence of diving ducks. Although water depth was not measured as a component of this study, the water level of wetlands would provide the closest surrogate to actual water depth. Therefore, it is not surprising that diving ducks and waterbirds are positively associated with water level. Although not included in the pair ordination joint plots, wooded uplands were an important environmental variable in both years for axis 2 for characterizing sites where Common Goldeneye and Bufflehead were present. Prior to the deployment of nest boxes, these 2 species would have relied solely on natural cavities for nest sites in the Buffalo Lake Moraine. Even though these species were utilizing nest boxes, the importance of wooded uplands reflects the placement of boxes on large trees within groves of native deciduous trees.

When Common Goldeneye and Bufflehead were removed from the pair ordinations, results were very similar (Figure 3.5). In both years of the ordination, all species of divers as well as Horned Grebe and American Coot remained positively correlated with axis 1, while all species of dabblers were negatively correlated with axis 1. However, the exclusion of Common Goldeneye and Bufflehead from the pair ordination altered the importance of wooded uplands as an environmental variable. Wooded uplands were no longer identified as an important environmental variable in either 1989 or 2003. Water level remained consistently identified, as the most important environmental variable for species with positive scores on axis 1 in both years. Permanent cover was consistently identified as an important environmental variable associated with species scores for dabbling ducks. Numerous studies have

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identified strong associations between the presence of breeding waterfowl and permanent cover in associated uplands. In North Dakota, Austin *et al.* (2001) found that increased percentage of annual cropland was the landscape variable that consistently negatively affected the number of breeding pairs for a variety of dabbling duck species. Klett *et al.* (1988) found that a variety of dabbling duck species preferred permanent cover for nesting and that nest success was higher in areas with greater amounts of permanent cover available.

I had predicted that waterfowl and waterbird communities reflect of environmental variables, which are associated with specific feeding and nesting requirements. Generally, that prediction was correct for wetlands and the presence of aquatic bird species pairs. However, the brood ordinations did not consistently separate feeding guilds. In the 1989 brood ordination, Canvasback disproportionately influenced the overall ordination (Figure 3.4). Horned Grebe and American Coot broods were positively correlated with water level, which is consistent with nest building and feeding requirements for these species (Stedman 2000 and Brisbin *et al.* 2002). However, water levels extending into emergent vegetation that is necessary for nest building is not a requirement specific for Horned Grebe and American Coot, but is a condition necessary for numerous other aquatic bird species included in the ordination, for example, Redhead, Canvasback and Ruddy Ducks all require water levels extending into emergent vegetation for nesting (Brua 2001, Mowbray 2002 and Woodin *et. al.* 2002).

The 2003 brood ordination generally partitioned foraging guilds as predicted. All species of divers had positive scores on axis 1 with the exception of Mallard; all species of dabbling ducks had negative scores on the same axis. However, Horned Grebe, Red-neck Grebe and American Coot had negative scores on axis 1, distinctly different from other diving aquatic birds. In contrast to the 1989 ordination, water level was not associated with diving ducks in the 2003 ordination as water level was negatively correlated with axis 1. Wetland type was positively correlated with axis 1 and the occurrence of diving ducks. In 2003, the Buffalo Lake Moraine was

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undergoing a significant drought and not surprisingly, diving ducks were occurring on the more permanent wetlands. Although not included in the brood ordination joint plots, wooded uplands were positively associated with the occurrence of Bufflehead and especially Common Goldeneye broods, similar to the pair ordinations.

When Common Goldeneye and Bufflehead were removed from the brood ordinations, community patterns remained similar. Canvasback continued to heavily influence the 1989 brood ordination and American Coot and Horned Grebe were separated from all other species in the ordination (Figure 3.7). In 2003, when Common Goldeneye and Bufflehead were included as environmental variables, Bufflehead was correlated with the occurrence of other diving duck species (Figure 3.9). When included in the 2003 brood ordination, Bufflehead was strongly associated with axis 1 and accordingly all other diving duck species. It is likely that the inclusion of Bufflehead as an important environmental variable (Figure 3.9) reflects similar wetland preference between Bufflehead and other divers. Not surprisingly, the importance of wooded uplands was greatly diminished with the exclusion of Common Goldeneye and Bufflehead from the brood ordination.

Increased densities of Common Goldeneye and Bufflehead in the Buffalo Lake Moraine were associated with the deployment of nest boxes beginning in 1989 (Chapter 2). Nest success is a significant factor limiting the growth of waterfowl populations and nest failure contributes to population declines (Cowardin et al. 1985, Klett et al. 1988). In response, resource managers have deployed nest boxes to increase waterfowl productivity (Coulter 1979, Dennis and Dow 1984, Savard 1988, Poysa and Poysa 2002). From a conservation perspective, the addition of nest boxes may have broad consequences to community composition by altering the suite of species interactions that occur, particularly since nest box users are often aggressive and/or territorial. When wetlands were tested for concordance with all species included in the analysis, results from Mantel tests and Protest approach showed statistically significant concordance between community structure for pairs and broods. When the analysis was completed with Common Goldeneye and Bufflehead

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removed from the data, concordance was even stronger between years. These data suggest that differences in densities of Common Goldeneye and Bufflehead in 1989 and in 2003 did not result in detectable shifts in community structure. Several mechanisms could explain why changes in Common Goldeneye and Bufflehead densities did not translate into detectable shifts in waterfowl and waterbird community structure.

Time allocation patterns that I observed in focal animals in the Buffalo Lake Moraine are generally consistent with a similar study conducted in the Cariboo Parklands of British Columbia on Barrow's Goldeneye and Bufflehead (Savard 1986). Specifically, Common Goldeneye and Bufflehead allocated the majority of time to resting and feeding; time allocated to aggressive interaction accounted for less than 15% of the total amount of time allocation. Previous studies and observations of aggressive displayed by Common Goldeneye and Bufflehead suggest interactions are typically directed to congeners rather than to a suite of aquatic bird species (Savard 1984). Results of my data concur with previous studies and showed that aggression by Common Goldeneye and Bufflehead was most often directed at congeners rather than other species. In fact, the level of aggression initiated by Common Goldeneye and directed towards congeners (84.6%) was remarkably similar to the amount of aggressive interactions Buffleheads directed towards congeners (75.8%). The amount of aggression initiated by Common Goldeneye and directed towards Bufflehead (41.0%) was very similar to intra-specific aggression (43.1%). In contrast, levels of intra-specific aggression initiated by Bufflehead (49.5%) were almost double the rates of aggression Bufflehead directed towards Common Goldeneye (26.4%).

Despite dabbling ducks being more abundant on study area wetlands, aggression by both Common Goldeneye and Bufflehead was more frequently directed at diving rather than dabbling ducks which was consistent with previous studies involving *Bucephala spp.* (Savard and Smith 1987). Savard and Smith (1986) hypothesized that inter-specific aggression by *Bucephala spp.* is directed towards species that share common food resources or have similar breeding plumages. They

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found that along with congeners, Barrow's Goldeneye were more likely to attack Blue-winged Teal, which has more similar breeding plumage, than other species of dabblers. By contrast, in the Buffalo Lake Moraine, Blue-winged Teal were the recipient of only 2 aggressive interactions during 42 hours of observation involving Common Goldeneye and Bufflehead despite Blue-winged Teal being an abundant species. While I cannot conclusively identify the underlying cause of aggressive behaviors by *Bucephala spp.* in the Buffalo Lake Moraine, the fact that the majority of aggressive interactions were within the same feeding guild (i.e., diving ducks), competitive interactions probably revolve around the protection of food resources during the spring breeding season (Thompson and Ankney 2002).

My behavioral observations revealed substantial variation in the extent that *Bucephala spp.* directed aggressive behaviors to non-*Bucephala spp.* among wetlands. While overall levels of aggressive behaviors by *Bucephala spp.* to non-*Bucephala spp.* were typically low, levels ranged from no recorded aggressive interactions per hour to 3 aggressive interactions per hour of observation on one particular wetland. This result suggests that *Bucephala spp.* may be capable of altering community structure through aggressive behaviors but that the conditions under which high levels of aggression occur are restricted to a relatively small number of wetlands. Lastly, while the conditions under which *Bucephala* display high levels of aggressive behaviors to non- *Bucephala spp.* are not well understood, they could be related to lake morphometry that promote high rates of encounters between participants (i.e., low habitat complexity), production levels (i.e., enhanced levels of aggression to defend limited food resources), or characteristics of the individual birds.

Conservation biologists use a diversity of remedial practices to increase the abundance and distribution of waterfowl. While these activities can meet management goals, they can potentially alter overall community structure by altering a suite of behavioral interactions related to resource defense. The results of my study suggest that increases in Common Goldeneye and Bufflehead, mediated by the

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deployment of nest boxes at the local spatial scale, did not result in dramatic shifts in the structure of waterbird and waterfowl communities in the Buffalo Lake Moraine. Although I found concordance between the structure of waterbird and waterfowl communities between periods of low and high density of Common Goldeneye and to a lesser extent Bufflehead, I believe that additional studies regarding potential impacts of territorial inter-specific aggression are warranted because my data suggested that rates of aggression interactions were highly variable amongst wetlands. I suggest that at a coarse landscape level, the overall waterfowl and waterbird community has not been negatively impacted, but that a localized scale (i.e. individual wetland), impacts on community structure in response to enhanced populations of Common Goldeneye may be possible.

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Appendix 3.1: Summary of transect attributes in the Buffalo Lake Moraine study area, located in central Alberta.

Transect	Road	Start	End	Length (km)	Area (km^2)	No. of Wetlands	Wetland Density ($\#/km^2$)
1	TWP 392	112 44'3"W 52 20'8" N	113 3'3"W 52 20'8" N	20.92	8.42	254	30.17
2	Hwy 601	112 44'3"W 52 24'3"N	113 9'0"W 52 24'3"N	27.37	11.01	216	19.62
3	TWP 404	112 38'6"W 52 27'8"N	113 10'3"W 52 27'8"N	16.09	6.48	129	19.91
4	TWP 412	112 35'6"W 52 31'3"N	113 10'3"W 52 31'3"N	19.31	7.77	157	20.21
5	HWY 53	112 35'6"W 52 34'8"N	113 10'3"W 52 34'8"N	38.62	15.54	323	20.79
6	TWP 424	112 37'1"W 52 38'2"N	113 10'3"W 52 38'2"N	37.01	14.89	358	24.04

Appendix 3.2: Summary (Mean (± SE)) of environmental variable for wetlands and associated uplands in the Buffalo Lake Moraine, in 1989 and 2003. Only wetlands used in Reciprocal Averaging ordinations for community analysis are included.

	1989		2003	
Variable	Pairs	Broods	Pairs	Broods
Margin (m)	7.15 ± 0.18	7.38 ± 0.35	7.82 ± 0.17	7.93 ± 0.32
Crop (%)	40.47 ± 2.13	40.71 ± 4.27	29.88 ± 2.04	31.72 ± 4.23
Tame (%)	26.98 ± 1.94	25.40 ± 4.00	39.55 ± 2.03	29.14 ± 3.82
Wooded (%)	18.80 ± 1.47	21.47 ± 3.14	20.96 ± 1.44	26.82 ± 3.22
Yard (%)	3.66 ± 0.76	1.92 ± 0.86	5.54 ± 0.92	3.63 ± 1.33
Grass (%)	10.32 ± 1.04	10.51 ± 2.16	4.08 ± 0.76	8.69 ± 2.33
Wetland Area (ha)	1.49 ± 0.26	2.69 ± 1.00	1.49 ± 0.26	2.69 ± 1.00
Wetland Perimeter	514.61 ± 28.43	623.40 ± 78.32	514.61 ± 28.43	623.40 ± 78.32
Per:Area	891.15 ± 40.09	698.21 ± 89	891.15 ± 40.09	698.21 ± 89
Proportion Wetlands	0.08 ± 0.001	0.10 ± 0.01	0.08 ± 0.001	0.10 ± 0.01

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Appendix 3.3: Frequency of occurrence (%) of breeding waterfowl and waterbird pairs and broods observed in the Buffalo Lake Moraine in 1989 and 2003. Frequency of occurrence is based on the presence of breeding pairs observed from 429 wetlands and the presence of broods from 99 wetlands.

			Frequency of occurrence (%) of pairs			**Frequency of occurrence (%) of broods**		
Common Name	Genus species	**Species Code**	**1989**	**2003**	+/-	**1989**	**2003**	+/-
Mallard	*Anas platyrhynchos*	MALL	67.60	47.32	-20.3	35.35	38.38	+3.0
Gadwall	*Anas strepera*	GADW	51.05	44.99	-6.1	19.19	27.27	+8.1
American Wigeon	*Anas americana*	WIGE	20.05	7.23	-12.9	7.07	6.06	-1.0
Green-winged Teal	*Anas crecca*	GRWT	14.22	12.59	-1.6	2.02	6.06	+4.1
Blue-winged Teal	*Anas discors*	BLWT	64.57	42.89	-21.7	36.36	46.46	+10.1
Northern Shoveler	*Anas clypeata*	SHOV	31.70	24.24	-7.5	16.16	17.17	+1.0
Northern Pintail	*Anas acyta*	PINT	12.35	3.26	-9.1	8.08	2.02	-6.1
Redhead	*Athya valisineria*	REDH	24.71	27.74	+3.0	4.04	10.10	+6.0
Canvasback	*Athya valisineria*	CANV	13.75	9.56	-4.2	8.08	3.03	-5.1
Lesser Scaup	*Athya affinis*	SCAU	39.16	27.97	-11.2	25.25	5.05	-20.2
Common Goldeneye	*Bucephala clangula*	GOLD	4.20	19.11	+14.9	2.02	21.21	+19.2
Bufflehead	*Bucephala albeola*	BUFF	12.82	24.01	+11.2	11.11	16.16	+5.1
Ruddy duck	*Oxyura jamaicensis*	RUDD	4.90	12.35	+7.5	5.05	5.05	0.0
American Coot	*Fulica americana*	COOT	5.36	24.71	+19.3	36.36	50.51	+14.1
Red-neck Grebe	*Podiceps grisegena*	RNGR	4.90	1.40	-3.5	12.12	2.02	-10.1
Horned Grebe	*Podiceps auritus*	HOGR	19.11	17.72	-1.4	23.23	10.10	-13.1

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Appendix 3.4: Results of Reciprocal Averaging (RA) for waterfowl and waterbird pairs in the Buffalo Lake Moraine, 1989. Pearson (r) and Kendall (tau) correlation coefficients are provided with ordination axes 1 and 2. N= 429. Environmental variables with r^2-values > 0.05 included in joint plots (***in bold***).

	Axis 1		**Axis 2**		**Total Inertia**
Eigenvalue	**0.275**		**0.238**		**2.43**
% variance explained	**11.32**		**9.79**		
Cumulative % variance	**11.32**		**21.11**		
Species Scores	**r**	**tau**	**r**	**tau**	
MALL	0.11	0.16	-0.07	-0.01	
GADW	-0.21	-0.14	-0.23	-0.18	
WIGE	-0.15	-0.12	0.28	0.32	
GRWT	-0.03	<0.01	0.10	0.13	
BLWT	-0.21	-0.13	0.13	0.17	
SHOV	-0.31	-0.25	-0.23	-0.21	
PINT	-0.20	-0.16	-0.27	-0.29	
REDH	0.47	0.43	-0.28	-0.26	
CANV	0.39	0.33	-0.26	-0.25	
SCAU	0.27	0.30	-0.09	-0.07	
GOLD	0.19	0.17	0.03	0.06	
BUFF	0.49	0.37	0.50	0.35	
RUDD	0.29	0.24	-0.14	-0.13	
COOT	0.25	0.21	-0.22	-0.19	
HOGR	0.21	0.23	-0.27	-0.25	
Environmental Variables					
TYPE	0.17	0.17	-0.02	-0.03	
LEVEL	0.20	0.16	-0.12	-0.16	
MARGIN	0.14	0.09	0.18	0.14	
CROP	**-0.11**	**-0.07**	**-0.23**	**-0.16**	
PERM_CV	-0.03	-0.02	0.07	0.05	
WOOD	0.14	0.09	0.17	0.13	
YARD	0.03	0.03	0.09	0.05	
GRASS	0.05	0.07	0.03	0.03	
AREA	0.08	0.09	0.10	-0.06	
PERIM	0.17	0.08	0.12	-0.06	
PER:AREA	-0.08	-0.09	0.03	0.06	
NORTHING	0.09	0.06	0.10	0.07	
EASTING	-0.02	0.01	0.03	0.03	
PROPORTION	0.21	0.15	0.15	0.07	

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Appendix 3.5: Results of Reciprocal Averaging (RA) for waterfowl and waterbird pairs in the Buffalo Lake Moraine, 2003. Pearson (r) and Kendall (tau) correlation coefficients are provided with ordination axes 1 and 2. N= 429. Environmental variables with r^2-values > 0.05 included in joint plots (***in bold***).

	Axis 1		**Axis 2**		**Total Inertia**
Eigenvalue	**0.349**		**0.272**		**3.00**
% variance explained	**11.63**		**9.01**		
Cumulative % variance	**11.63**		**20.64**		
Species	**r**	**tau**	**r**	**tau**	
MALL	-0.04	0.05	-0.09	-0.09	
GADW	-0.23	-0.16	0.18	0.17	
WIGE	-0.06	-0.04	0.05	0.05	
GRWT	-0.03	0.03	0.21	0.19	
BLWT	-0.11	-0.04	0.24	0.23	
SHOV	-0.17	-0.14	0.41	0.34	
PINT	0.07	0.09	-0.01	-0.01	
REDH	0.16	0.24	-0.03	-0.02	
CANV	0.18	0.21	-0.07	-0.07	
SCAU	0.12	0.19	-0.22	-0.23	
GOLD	-0.22	-0.19	-0.39	-0.35	
BUFF	-0.40	-0.34	-0.45	-0.40	
RUDD	0.13	0.19	-0.13	-0.14	
COOT	0.72	0.57	-0.04	-0.04	
HOGR	0.29	0.30	-0.20	-0.23	
Environmental Variables					
TYPE	0.12	-0.12	-0.21	-0.20	
LEVEL	**0.27**	**0.27**	**-0.08**	**-0.08**	
MARGIN	-0.17	-0.14	-0.06	-0.03	
CROP	0.15	0.15	0.04	0.01	
PERM_CV	-0.10	-0.11	0.14	0.11	
WOOD	-0.13	-0.10	-0.20	-0.16	
YARD	0.03	0.03	-0.01	-0.06	
GRASS	0.08	0.06	-0.08	-0.05	
AREA	0.03	-0.06	-0.06	-0.09	
PERIM	-0.05	<0.01	-0.08	-0.08	
PER:AREA	0.08	0.07	0.08	0.11	
NORTHING	-0.03	0.02	0.04	0.04	
EASTING	**-0.27**	**-0.19**	**-0.05**	**-0.02**	
PROPORTION	-0.04	-0.10	-0.16	-0.13	

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Appendix 3.6: Results of Reciprocal Averaging (RA) for waterfowl and waterbird pairs in the Buffalo Lake Moraine, 1989. Common Goldeneye and Bufflehead were excluded from the ordination and the species presence were used as environmental variables. Pearson (r) and Kendall (tau) correlation coefficients are provided with ordination axes 1 and 2. N= 412. Environmental variables with r^2-values > 0.05 included in joint plots (***in bold***).

	Axis 1		**Axis 2**		**Total Inertia**
Eigenvalue	**0.271**		**0.227**		**2.10**
% variance explained	**12.90**		**10.81**		
Cumulative % variance	**12.90**		**23.71**		
Species	**r**	**tau**	**r**	**tau**	
MALL	0.14	0.18	-0.03	-0.06	
GADW	-0.07	-0.02	-0.19	-0.22	
WIGE	-0.26	-0.21	0.51	0.43	
GRWT	-0.11	-0.09	0.30	0.30	
BLWT	-0.22	-0.14	0.11	0.10	
SHOV	-0.24	-0.19	-0.51	-0.44	
PINT	-0.10	-0.06	-0.36	-0.33	
REDH	0.58	0.49	0.04	0.05	
CANV	0.50	0.38	-0.07	-0.08	
SCAU	0.33	0.34	0.06	0.05	
RUDD	0.35	0.26	0.07	0.09	
COOT	0.31	0.23	-0.09	-0.11	
HOGR	0.32	0.30	0.07	0.07	
Environmental Variables					
TYPE	0.17	0.17	0.10	0.09	
LEVEL	**0.23**	**0.17**	**-0.03**	**-0.05**	
GOLD	0.11	0.11	0.06	0.06	
BUFF	0.12	0.11	0.05	0.07	
MARGIN	0.03	0.02	0.11	0.05	
CROP	0.03	0.01	-0.09	-0.04	
PERM_CV	-0.09	-0.06	0.01	-0.03	
WOOD	0.05	0.04	0.07	0.07	
YARD	-0.01	<0.01	0.06	0.04	
GRASS	0.03	0.06	<0.01	0.02	
AREA	0.01	0.01	0.03	<0.01	
PERIM	0.09	0.01	0.08	<0.01	
PER:AREA	-0.09	-0.10	<0.01	<0.01	
NORTHING	0.03	0.02	0.08	0.06	
EASTING	-0.01	0.01	0.09	0.05	
PROPORTION	0.13	0.11	0.12	0.12	

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Appendix 3.7: Results of Reciprocal Averaging (RA) for waterfowl and waterbird pairs in the Buffalo Lake Moraine, 2003. Common Goldeneye and Bufflehead were excluded from the ordination and the species presence were used as environmental variables. Pearson (r) and Kendall (tau) correlation coefficients are provided with ordination axes 1 and 2. N= 412. Environmental variables with r^2-values > 0.05 included in joint plots (***in bold***).

	Axis 1		**Axis 2**		**Total Inertia**
Eigenvalue	**0.344**		**0.287**		**2.75**
% variance explained	**12.51**		**10.44**		
Cumulative % variance	**12.51**		**22.95**		
Species	**r**	**tau**	**r**	**tau**	
MALL	-0.06	0.02	-0.59	-0.50	
GADW	-0.31	-0.22	-0.14	-0.16	
WIGE	-0.07	-0.05	-0.04	-0.04	
GRWT	-0.05	-0.01	0.29	0.27	
BLWT	-0.18	-0.11	0.49	0.43	
SHOV	-0.29	-0.23	0.26	0.24	
PINT	0.10	0.11	0.14	0.14	
REDH	0.18	0.24	0.05	0.05	
CANV	0.20	0.21	<0.01	-0.02	
SCAU	0.24	0.28	-0.02	-0.02	
RUDD	0.21	0.24	0.03	0.03	
COOT	0.69	0.55	0.09	0.09	
HOGR	0.36	0.34	0.09	0.08	
Environmental Variables					
TYPE	0.01	0.01	0.10	0.02	
LEVEL	**0.30**	**0.31**	**0.07**	**0.09**	
GOLD	-0.02	0.03	0.02	0.01	
BUFF	-0.11	-0.06	-0.02	-0.01	
MARGIN	-0.13	0.02	-0.10	<-0.01	
CROP	0.13	0.13	<0.01	<0.01	
PERM_CV	-0.15	-0.15	0.05	0.05	
WOOD	-0.03	<-0.01	-0.04	-0.07	
YARD	-0.01	0.03	-0.06	-0.05	
GRASS	0.12	0.09	<0.01	0.02	
AREA	0.06	-0.02	-0.04	-0.02	
PERIM	<-0.01	-0.01	-0.01	<-0.01	
PER:AREA	0.05	0.02	0.02	0.03	
NORTHING	-0.03	0.01	<0.01	0.01	
EASTING	**-0.24**	**-0.18**	**-0.04**	**-0.04**	
PROPORTION	0.04	-0.01	-0.10	-0.08	

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Appendix 3.8: Results of Reciprocal Averaging (RA) for waterfowl and waterbird broods in the Buffalo Lake Moraine, 1989. Pearson (r) and Kendall (tau) correlation coefficients are provided with ordination axes 1 and 2. N= 96. Environmental variables with r^2-values > 0.05 included in joint plots (***in bold***).

	Axis 1		**Axis 2**		**Total Inertia**
Eigenvalue	**0.541**		**0.471**		**4.47**
% variance explained	**12.10**		**10.54**		
Cumulative % variance	**12.10**		**22.64**		
Species Scores	**r**	**tau**	**r**	**tau**	
MALL	-0.22	-0.26	-0.32	-0.26	
GADW	-0.15	-0.18	-0.16	-0.11	
WIGE	-0.07	-0.06	-0.09	-0.06	
BLWT	<-0.01	0.20	-0.07	0.07	
SHOV	-0.15	-0.22	-0.05	0.02	
PINT	-0.12	-0.17	-0.06	-0.02	
REDH	-0.10	-0.15	-.02	0.06	
CANV	0.80	0.40	-0.12	-0.09	
SCAU	-0.17	-0.22	-0.32	-0.27	
GOLD	-0.08	-0.12	-0.13	-0.12	
BUFF	0.11	0.29	-0.33	-0.27	
RUDD	-0.08	-0.06	0.04	0.08	
COOT	-0.06	0.14	0.73	0.62	
RNGR	-0.20	-0.33	-0.18	-0.16	
HOGR	<0.01	0.23	0.33	0.38	
Environmental Variables					
TYPE	0.09	<0.01	-0.07	-0.04	
LEVEL	**0.11**	**0.05**	**0.30**	**0.22**	
MARGIN	-0.01	-0.05	-0.09	0.01	
CROP	0.03	0.11	0.13	0.13	
PERM_CV	0.05	-0.07	0.06	0.05	
WOOD	-0.10	<0.01	-0.18	-0.17	
YARD	-0.08	-0.09	0.05	0.04	
GRASS	0.03	-0.09	-0.11	-0.16	
AREA	-0.02	0.13	0.05	<0.01	
PERIM	0.08	0.01	0.01	-0.03	
PER:AREA	-0.17	-0.09	-0.01	-0.04	
NORTHING	**-0.08**	**-0.05**	**-0.23**	**-0.11**	
EASTING	**0.08**	**<0.01**	**-0.29**	**-0.17**	
PROPORTION	-0.01	0.02	-0.03	-0.12	

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Appendix 3.9: Results of Reciprocal Averaging (RA) for waterfowl and waterbird broods in the Buffalo Lake Moraine, 2003. Pearson (r) and Kendall (tau) correlation coefficients are provided with ordination axes 1 and 2. N= 96. Environmental variables with r^2-values > 0.05 included in joint plots (***in bold***).

	Axis 1		**Axis 2**		**Total Inertia**
Eigenvalue	**0.460**		**0.438**		**3.65**
% variance explained	**12.60**		**12.00**		
Cumulative % variance	**12.60**		**24.60**		
Species	**r**	**tau**	**r**	**tau**	
MALL	0.44	0.47	-0.10	0.09	
GADW	-0.04	0.03	-0.05	0.11	
WIGE	-0.05	-0.03	0.14	0.21	
BLWT	-0.11	-0.07	-0.05	0.17	
SHOV	-0.32	-0.28	-0.01	0.10	
PINT	-0.04	-0.03	-0.13	-0.18	
REDH	0.26	0.25	-0.15	-0.17	
CANV	0.09	0.11	-0.07	-0.03	
SCAU	0.14	0.14	-0.05	-0.01	
GOLD	0.07	0.13	0.78	0.57	
BUFF	0.63	0.46	-0.12	-0.11	
RUDD	0.11	0.14	-0.11	-0.11	
COOT	-0.56	-0.49	-0.40	-0.45	
RNGR	-0.14	-0.12	0.07	0.14	
HOGR	-0.02	0.02	-0.01	0.08	
Environmental Variables					
TYPE	**0.23**	**0.29**	**0.19**	**0.18**	
LEVEL	**-0.19**	**-0.17**	**-0.22**	**-0.23**	
MARGIN	**0.16**	**0.14**	**0.22**	**0.12**	
CROP	-0.12	-0.19	-0.20	-0.11	
PERM_CV	<-0.01	0.03	-0.05	0.01	
WOOD	**0.22**	**0.20**	**0.35**	**0.07**	
YARD	0.08	0.10	-0.09	-0.06	
GRASS	-0.12	-0.11	0.02	0.12	
AREA	-0.14	0.09	0.02	0.14	
PERIM	-0.07	0.09	0.05	0.14	
PER:AREA	-0.09	-0.07	-0.10	-0.13	
NORTHING	0.05	-0.01	-0.21	-0.13	
EASTING	**0.22**	**0.15**	**0.19**	**0.21**	
PROPORTION	0.04	0.08	0.06	0.15	

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Appendix 3.10: Results of Reciprocal Averaging (RA) for waterfowl and waterbird broods in the Buffalo Lake Moraine, 1989. Common Goldeneye and Bufflehead were excluded from the ordination and the species presence were used as environmental variables. Pearson (r) and Kendall (tau) correlation coefficients are provided with ordination axes 1 and 2. N= 89. Environmental variables with r^2-values > 0.05 included in joint plots (***in bold***).

	Axis 1		**Axis 2**		**Total Inertia**
Eigenvalue	**0.560**		**0.492**		**3.90**
% variance explained	**14.36**		**12.62**		
Cumulative % variance	**14.36**		**26.98**		
Species	**r**	**tau**	**r**	**tau**	
MALL	-0.25	-0.32	-0.31	-0.21	
GADW	-0.16	-0.19	-0.20	-0.16	
WIGE	-0.07	-0.03	-0.21	-0.22	
BLWT	0.04	0.29	-0.21	-0.01	
SHOV	-0.14	-0.91	-0.17	-0.12	
PINT	-0.11	-0.10	-0.14	-0.11	
REDH	-0.08	-0.10	-0.05	0.01	
CANV	0.82	0.41	-.21	-0.20	
SCAU	-0.19	-0.22	-0.32	-0.29	
RUDD	-0.09	-0.09	<-0.01	0.08	
COOT	-0.05	0.22	0.71	0.62	
RNGR	-0.20	-0.29	-0.13	-.04	
HOGR	0.03	0.31	0.41	0.40	
Environmental Variables					
TYPE	0.11	0.01	-0.13	-0.05	
LEVEL	**0.16**	**0.15**	**0.25**	**0.23**	
MARGIN	0.02	-0.10	0.04	-0.03	
GOLD	-0.08	-0.13	-0.09	-0.06	
BUFF	0.01	-0.01	-0.01	-0.03	
CROP	0.07	0.20	0.01	0.08	
PERM_CV	0.08	-0.03	0.03	0.04	
WOOD	-0.16	-0.13	-0.01	-0.04	
YARD	-0.08	-0.11	0.02	0.03	
GRASS	-0.01	-0.20	-0.06	-0.16	
AREA	-0.03	0.13	0.09	0.03	
PERIM	0.07	0.13	0.11	0.01	
PER:AREA	-0.18	-0.11	-0.11	-0.06	
NORTHING	-0.10	-0.06	-0.15	-0.08	
EASTING	**0.09**	**<-0.01**	**-0.32**	**-0.21**	
PROPORTION	-0.04	-0.05	0.06	-0.07	

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Appendix 3.11: Results of Reciprocal Averaging (RA) for waterfowl and waterbird broods in the Buffalo Lake Moraine, 2003. Common Goldeneye and Bufflehead were excluded from the ordination and the species presence were used as environmental variables. Pearson (r) and Kendall (tau) correlation coefficients are provided with ordination axes 1 and 2. N= 89. Environmental variables with r^2-values > 0.05 included in joint plots (***in bold***).

	Axis 1		**Axis 2**		**Total Inertia**
Eigenvalue	**0.454**		**0.401**		**3.09**
% variance explained	**14.69**		**12.98**		
Cumulative % variance	**14.69**		**27.67**		
Species	**r**	**tau**	**r**	**tau**	
MALL	0.70	0.60	-0.52	-0.42	
GADW	0.10	0.15	-0.22	-0.19	
WIGE	-0.16	-0.14	-0.34	-0.27	
BLWT	-0.20	-0.11	-0.15	-0.11	
SHOV	-0.38	-0.34	-0.06	-0.05	
PINT	0.09	0.09	0.22	0.15	
REDH	0.50	0.38	0.31	0.27	
CANV	0.20	0.17	0.13	0.11	
SCAU	0.36	0.28	0.14	0.12	
RUDD	0.28	0.22	0.18	0.16	
COOT	-0.42	-0.35	0.72	0.62	
RNGR	-0.14	-0.10	-0.03	-0.03	
HOGR	0.07	0.12	<0.01	0.02	
Habitat Variables					
TYPE	0.11	0.20	-0.12	-0.13	
LEVEL	**-0.19**	**-0.16**	**0.33**	**0.29**	
MARGIN	0.10	0.09	-0.05	-0.06	
GOLD	0.05	0.06	-0.12	-0.10	
BUFF	**0.23**	**0.20**	**-0.07**	**-0.06**	
CROP	-0.06	-0.04	0.10	0.11	
PERM_CV	-0.08	-0.06	-0.08	-0.09	
WOOD	0.19	0.14	-0.01	-0.05	
YARD	0.14	0.11	-0.05	<0.01	
GRASS	-0.07	-0.10	-0.02	-0.03	
AREA	-0.14	0.03	0.04	-0.07	
PERIM	-0.11	0.03	-0.03	-0.11	
PER:AREA	-0.06	-0.03	0.01	0.04	
NORTHING	0.01	-0.01	0.10	0.13	
EASTING	**0.09**	**0.06**	**-0.29**	**-0.24**	
PROPORTION	-0.09	-0.07	0.06	-0.05	

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Chapter 4

Summary, Management Recommendations and Future Research

Summary of Chapter 2

The role of artificial nest boxes in influencing population trends for Common Goldeneye (Bucephala clangula) and Bufflehead (Bucephala albeola) in the Buffalo Lake Moraine.

Objectives

The overall objective of Chapter 2 was to evaluate the effectiveness of nest boxes to increase breeding populations of cavity-nesting waterfowl in central Alberta. The specific objectives were 4-fold. First, my preliminary analyses indicated that densities of Common Goldeneye and Bufflehead in the Buffalo Lake Moraine have increased since 1989. While the increase in densities of Bufflehead and Common Goldeneye could arise from the deployment of nest boxes in the Buffalo Lake Moraine, an alternative hypothesis is that these increases reflect an increase in densities of both species at a larger spatial scale and that they merely coincide with deployment of nest boxes. As a result, I initially compared temporal changes in densities of Bufflehead and Common Goldeneye at the local scale of the Buffalo Lake Moraine (1,295 km^2) where nest boxes had been deployed, with that at the larger regional spatial scale of Stratum 26 (i.e. 90,280 km^2). These data were analyzed to compare temporal variation of the abundance of cavity-nesting waterfowl with other species of waterfowl and waterbirds. Second, I examined the relationship between waterfowl and waterbird abundance and wetland density at both the regional and local spatial scale. I completed these analyses to examine the similarities between the relationship of wetland density and abundance of cavity-nesting waterfowl compared to other waterfowl and waterbird species. Third, I quantified variation in the occupancy of nest boxes over a 16-year period in the Buffalo Lake Moraine to determine if changes in Bucephala spp. populations during that time period paralleled nest box occupancy patterns. Fourth, I completed a 2-year nest box

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manipulation experiment to test the hypothesis that Common Goldeneye and Bufflehead populations in the Buffalo Lake Moraine are limited by the availability of nest cavities.

Summary of primary results

Temporal trends in waterfowl and waterbird density

At the larger regional spatial scale, my analyses provided little evidence of increasing densities of waterfowl populations. In fact, linear regression models (13 of the 13 species models) revealed that waterfowl density was stable (i.e., unrelated to year; $P > 0.05$) throughout the 16-year study period (i.e., extending from 1989 to 2004), including densities of Common Goldeneye and Bufflehead. Only the density of American Coot was statistically ($P < 0.05$) and negatively related to year. Similarly, analyses completed at the local spatial scale, showed that densities of the majority of waterfowl species in the Buffalo Lake Moraine (i.e., at the local scale) were stable (13 of the 13 species) over the 16-year study period (Table 2). However, only two species demonstrated positive, but not significant correlations with year throughout the study period, Common Goldeneye and Bufflehead.

Density of waterfowl species versus wetland density

At stratum scale, linear regression models revealed positive relationships between densities of waterfowl species and annual wetland densities (11 of 13 species), however, relationships were statistically significant for only 2 species, Redhead and Canvasback. Within the Buffalo Lake Moraine, there was a strong correlation between annual wetland density and the majority of diving ducks. Redhead, Canvasback, Lesser Scaup and Ruddy Duck all demonstrated positive and significant relationships between wetland density and breeding density. Both Common Goldeneye and Bufflehead exhibited very weak relationships between wetlands and breeding densities.

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Temporal variation in the occupancy of nest boxes

Occupancy of available nest boxes by Common Goldeneye increased gradually from about 10% in 1989 to about 85% percent in 1993. Since that time nest box occupancy has remained relatively constant, ranging from 82 to 96%. In 2004, approximately half of the existing nest boxes located along transects in the Buffalo Lake Moraine study area were closed, as part of the nest box manipulation experiment. Of the remaining usable boxes in 2004 (N= 47 nest boxes) 92% were occupied by Common Goldeneye. Following a similar pattern, Bufflehead nest box occupancy gradually increased from approximately 7.5% in 1991 to 31.3% in 1994. Since 1994, Bufflehead nest box occupancy has remained between 30% and 59%.

Nest box manipulation

Responses by Common Goldeneye and Bufflehead to nest box exclosure were species-specific. Mean number of pairs of Common Goldeneye did not differ significantly between clusters of wetlands where nest boxes were available for occupancy compared to clusters where nest boxes were closed. In contrast, the mean number of Common Goldeneye broods and brood size were significantly higher from clusters where nest boxes were available compared to those where nest boxes were closed. This result suggests that the availability of nest boxes limited reproductive output by Common Goldeneye hens, but did not affect the use of wetlands by Common Goldeneye pairs. In contrast, for Bufflehead the mean numbers of pairs and the mean number of broods did not differ significantly between clusters with open versus closed boxes, although the number of broods tended to be lower in the closed clusters. However, the mean brood size differed significantly between clusters of open and closed nest boxes. Differences in the number and size of Common Goldeneye and Bufflehead broods between wetlands where nest boxes were available for occupancy is likely due to the manipulation of nest box availability rather than differences in characteristics of wetlands within each cluster.

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Summary of Chapter 3

Response of waterfowl and waterbird community assemblages due to increased populations of Common Goldeneye (Bucephala clangula) and Bufflehead (Bucephala albeola) in the Buffalo Lake Moraine.

Objectives

The overall objective of Chapter 3 was to broadly address the question of whether increases in the abundance of Common Goldeneye and Bufflehead influence the overall structure of waterfowl and waterbird communities in the Buffalo Lake Moraine. In order to assess the response of waterfowl and waterbird communities to increased breeding populations of Common Goldeneye and Bufflehead, my specific objectives were 3 fold. First, I examined the structure of pairs and broods of aquatic bird communities on wetlands (n=498 for pairs, n=96 for broods) in the Buffalo Lake Moraine. I also examined the relationship between community structure and environmental variables. Second, I tested for concordance in the structure of waterfowl and waterbird communities on study area wetlands before (1989) and after (2003) increased densities of Common Goldeneye and Bufflehead. Third, I conducted focal animal sampling of Common Goldeneye and Bufflehead in the Buffalo Lake Moraine to examine intra and inter-specific aggression involving Common Goldeneye and Bufflehead which may explain patterns in community structure.

Summary of primary results

<u>Occurrence of waterfowl and waterbirds</u>

Mallard, Gadwall and Blue-winged Teal and to a lesser extent, American Wigeon, Northern Shoveler, Redhead and Lesser Scaup pairs were the most frequently occurring species in the Buffalo Lake Moraine. Similarly, broods produced

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by Mallards, Blue-winged Teal were also the most frequently encountered. In contrast to many species, the occurrence of Common Goldeneye and Bufflehead and presence of broods for both of these species increased substantially between 1989 and 2003.

General relationship between community structure and environmental variables

Pairs

Reciprocal averaging ordinations completed for waterfowl and waterbird pairs indicated differences between aquatic communities in the BLM study area, generally separating species by foraging guilds. In both years of the majority of dabblers were grouped together, whereas divers formed distinct clusters within the species ordinations. One notable exception was the location of both Common Goldeneye and Bufflehead in the 2003 ordinations. This result supports evidence from Chapter 2, that Common Goldeneye and Bufflehead are responding to different environmental variables compared to other species of waterfowl in the Buffalo Lake Moraine.

For RA ordinations completed for pairs water level was consistently one of the most important environmental variable, particularly with the strong positive correlation with species scores for diving ducks. Although not as strong, wetland type was also an important environmental variable. Wooded uplands were identified an important factor correlated with the presence of both Common Goldeneye and Bufflehead. For the ordinations completed for 2003, Easting, water level and wetland type were generally more important in 2003 when compared to 1989. The importance of these three environmental variables in 2003, compared to 1989 may be reflective of drought conditions experienced in the Buffalo Lake Moraine during the 2003 breeding season and the different wetland types associated with and East – West gradient within the Buffalo Lake Moraine.

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Broods

In 1989, brood ordinations did not result in separation of waterfowl and waterbird along feeding guilds to the extent, which occurred with the pair ordination. When Common Goldeneye and Bufflehead were removed from the 1989 brood ordinations, community patterns were not altered to any noticeable degree. Generally, results of the 2003 ordinations reflected separation of species scores based on foraging guilds, similar to the pair ordinations. All species scores for divers formed clusters similar to results of the pair ordinations; however American Coot, Horned Grebe and Red-necked Grebe species scores were negatively correlated with axis 1, distinctly different from pair ordination results. In 2003, Canvasback, Lesser Scaup, Redhead and Ruddy Duck species scores were all very similar, with both Common Goldeneye and Bufflehead species scores visibly different from these other species of diving ducks.

For brood ordinations that included all species, water level and Easting were significantly correlated in both 1989 and 2003. Both water level and Easting were identified as significant environmental variables in the pair ordinations and these two factors remain important factors for broods as well. Additionally, wooded uplands and Northing were identified as important environmental variables in both years. In 2003, wooded upland cover (r=0.35; axis 2) had the highest correlation coefficient of any environmental variable for any ordination completed. Not surprisingly, wooded uplands were strongly associated with the presence of Common Goldeneye broods. Similar to the pairs, Easting was a significant variable for the brood ordination; however, there was little relationship between Easting and specific feeding guilds. When Common Goldeneye and Bufflehead were removed from the brood ordination, fewer environmental variables remained significant, except water level and Easting for both the 1989 and 2003 ordinations.

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Evaluating the effects of Common Goldeneye and Bufflehead on Community Structure

I tested for effects of increased densities of Common Goldeneye and Bufflehead on waterfowl and waterbird communities by comparing concordance between aquatic bird communities in 1989, when densities were low and in 2003, when densities were high. Results of both the Mantel tests and the PROTEST method rejected the null hypothesis of no similarity between the 2 time periods, a $P<0.10$. This result was observed using data describing the presence of pairs with all species included in analysis and when Common Goldeneye and Bufflehead were removed. Concordance between time periods was also observed when wetlands were analyzed for the presence of broods with all species included in analysis and when Common Goldeneye and Bufflehead were removed. These data suggest that aquatic bird communities did not change between 1989 and 2003 in response to increased densities of Common Goldeneye and Bufflehead.

Behavioral Observations and Intra and Inter-specific aggression

Focal animal sampling

Territorial drake Common Goldeneye and Bufflehead allocated the majority of time during egg-laying and early-incubation periods to resting (which included swimming and sleeping), followed by feeding and preening. Combined, these 3 activities accounted for >80% of the estimated time budget for both species. Both species allocated a low percent of time to aggressive behaviors (i.e. threat, attack and fight), and to display.

Intra and inter-specific aggression

The majority of aggressive interactions by both Common Goldeneye and Bufflehead were directed at congeners and accounted for 84.6% (Common Goldeneye) and 75.8% (Bufflehead) of all aggressive interactions. Inter-specific

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aggression initiated by Common Goldeneye involved interactions with 8 different species of waterfowl, whereas inter-specific aggression instigated by Bufflehead involved 6 species of waterfowl. Taken together, these data suggest that the lack of community-wide effects of increased densities of Bufflehead and Common Goldeneye between 1989 and 2003, is not too surprising as aggressive behavior by Bufflehead and Common Goldeneye are typically directed Bucephala spp.

MANAGEMENT RECOMMENDATIONS AND FUTURE RESEARCH

Nest boxes have been widely used to enhance a variety of cavity-nesting waterfowl populations in a range of landscapes. My research demonstrated that the provision of nest boxes is an effective management tool to enhance local populations of Common Goldeneye and to a lesser extent Bufflehead. I propose that nest box programs can be expanded to additional landscapes within the Aspen Parkland of central Alberta without altering overall aquatic bird communities. The lack of natural cavities within the Buffalo Lake Moraine, has limited the size of populations of these 2 species of cavity nesting waterfowl and a nest box program enhanced natural populations of Common Goldeneye and Bufflehead. It is likely that within the Buffalo Lake Moraine, the abundance of natural cavities will never increase to levels that could naturally support the current populations. Continued loss of wooded uplands to agricultural expansion and industrial activities and natural events such as drought and insect infestations may prevent native deciduous trees from reaching the necessary size needed to develop cavities required for cavity nesting waterfowl. If current population levels are to be maintained, the nest box program must be continued.

As the 2 study species continue to rely heavily on nest boxes for nesting in the Buffalo Lake Moraine, further research regarding density dependent factors affecting population size, such as, food resources and territory size may be warranted. I found that levels of aggression initiated by *Bucephala spp.* and directed at a variety of waterfowl species is highly variable. Reasons for this variation in aggressive

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interactions are unknown but may be related to specific characteristics of individual wetlands, such as wetland size, shoreline structure or wetland productivity.

Within the Buffalo Lake Moraine, Common Goldeneye and Bufflehead were present and successfully reproducing prior to the provision of nest boxes; so why it is desirable to artificially enhance populations of native wildlife to levels that may not be naturally sustainable? I believe the answer is two-fold. First, nest boxes are an inexpensive management tool that has been shown to effectively enhance populations. My research suggests that increased populations of Common Goldeneye and Bufflehead did not alter aquatic bird communities at a local scale. The enhancement of populations through nest boxes provides sportsmen increased opportunities to hunt and harvest desired wildlife species. Sportsman often fund conservation programming through direct and indirect means and I believe that increasing desired waterfowl population is an effective means to providing direct benefits to people who support and fund many conservation initiatives. Secondly, and more importantly, implementation of a nest box program can be an effective means of integrating wetland and habitat retention in stewardship programming. By working with private landowners in the installation, maintenance and monitoring of nest boxes it is possible to provide valuable education and extension information to individuals regarding the value in the retention of native wooded uplands and associated wetlands. Educated private citizens have, in turn, the ability to make meaningful land use decisions that will ensure the integrity of wetlands and support a diversity of wildlife.

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