University of Alberta

Persistence and abundance of the Western Grebe (*Aechmophorus occidentalis)* in Alberta

by

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For my family, who have always supported my passion for wildlife
whether it be unicorns or Western Grebes

ABSTRACT

The Western Grebe (*Aechmophorus occidentalis,* WEGR) is a Species of Special Concern in Alberta, declining in distribution and abundance. I evaluated how environmental variables including emergent vegetation, human developments, and prey availability affected WEGR persistence and abundance on 43 lakes in Alberta that historically supported WEGR. Persistence and abundance of WEGR were correlated, and both were positively associated with shoreline bulrush (*Scirpus lacustris*) and human development within a 500m buffer surrounding the lake, while inversely associated with surrounding forest. Bulrush provides important habitat for nesting, and WEGR are likely to occur on the same large fish-bearing lakes that humans prefer for recreation. However, this relationship with development puts grebes at risk for disturbance and habitat loss—a primary threat to endangered birds. I recommend shoreline vegetation be protected for the success of breeding grebes, and human activity around colonies should be kept to a minimum to curb further WEGR decline.

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CHAPTER ONE

GENERAL INTRODUCTION

The Western Grebe (*Aechmophorus occidentalis*), a member of the Family Podicipedidae, is the largest of seven grebe species that breed and winter in North America (Storer and Nuechterlein 1992). The Western Grebe is a colonial waterbird often referred to as the "swan grebe" due to its long, graceful neck (Semenchuk 1992). Closely resembling the Clark's Grebe (*Aechmophorus clarkii*), the Western Grebe was listed as its own species in 1985 (Monroe et al. 1985; Ahlquist et al. 1987). Prior to this, both the Clark's Grebe and the Western Grebe were thought to be color morphs of the latter species.

The Western Grebe ranges from central Canada to central Mexico, wintering along the Gulf and Pacific coasts (Fig. 1.1). In Alberta, this migratory species occurs in most areas of the province except the Canadian Shield (Yanch 2006; Semenchuk 2007). Colony size is variable with both regionally important (over 500 birds) and nationally important (over 1,000 birds) breeding colonies identified in the province (Poston et al. 1990). However, most colonies in Alberta no longer meet these criteria.

The species is present in Alberta from mid-April to late September, with mating and nest-site selection occurring soon after arrival in the spring. Mating rituals include an intricate synchronized "dance" in which a pair of Western Grebes rushes across the water simultaneously, giving the illusion that they are running on water.

Nests are constructed from various wetland plant species and appear as floating rafts anchored to emergent vegetation, such as bulrush (*Scirpus lacustris*), common reed (*Phragmites australis*), and cattail (*Typha* spp.) (Nuechterlein 1975; Lindvall and Low 1982). Both the male and female participate in nest building and incubation, which lasts 23-24 days (Lindvall and Low 1982). Clutch sizes in Alberta average 2.14 eggs (Hanus et al. 2002; Found and Hubbs 2004), while average clutch sizes in other regions range from 2.16 to 3.7 eggs (Storer and Nuechterlein 1992). After hatching, Western Grebes leave the nesting area and the chicks ride on either parent's back until two to four weeks old. Recruitment is typically low, ranging from 0.35 young per adult at Bear River Migratory Bird Refuge in Utah (Lindvall and Low 1982) to between 0.6-0.79 young per adult on lakes in Alberta and British Columbia, respectively (Forbes 1988; Hanus et al. 2002).

Western Grebes are almost exclusively piscivorous, with a small portion of their diet consisting of mollusks and arthropods (Lawrence 1950; Storer and Nuechterlein 1992). Their requirement for fish-bearing lakes along with their preference for deep waterbodies (Found et al. 2008) often puts them in conflict with humans because these lake characteristics are also attractive attributes for shoreline development and recreational activity. Wakes from boating activity as well as waves from high winds or storms can easily swamp nests (Berg et al. 2004; Allen et al. 2008). Disturbance to nesting habitat during winter months can affect breeding success for the following year; snowmobiles and shifting ice can scour old emergent vegetation, reducing nesting material available to Western

Grebes upon their arrival at breeding grounds (Berg et al. 2004). Western Grebes also are vulnerable to large-scale impacts such as oil spills on both their wintering and breeding grounds.

As of 2006, Alberta's Western Grebes constituted 13-19% of the world's estimated population of 70,000-100,000 (O'Donnel and Fjeldså 1997; Yanch 2006). Recent decline in abundance of Western Grebes in Alberta during the past several years has been documented by nest and brood counts, primarily in the Parkland and Boreal regions (Found and Hubbs 2004, Semenchuk 2007). The Western Grebe also has shown declines in other breeding areas outside of Alberta (Burger 1997) as well as on its wintering grounds (Puget Sound Action Team 2004).

While some of the decline in Alberta is attributable to reduced distribution and the loss of grebes from several lakes where they occurred historically, much of the decline is within breeding colonies (Kemper et al. 2008). According to historical records over the past 40 years on 43 different lakes, Alberta may have once been home to over 22,000 Western Grebes. Now, only 27 of these lakes are occupied, supporting an estimated 5,400 grebes—a 37% reduction in distribution and 76% reduction in total abundance (Yanch 2006; ASRD unpublished data). Because of the decline, along with the species' sensitivity to habitat disturbance, the Alberta Endangered Species Conservation Committee listed the Western Grebe as a Species of Special Concern in June 2006 (Alberta Sustainable Resource Development 2009). This has prompted the need for continued monitoring and research into causes of reduced abundance of Western Grebes, and in some cases, loss of entire populations on Alberta's lakes.

My objective is to understand probable reasons for the decline of the Western Grebe in Alberta by addressing both persistence and abundance. I use Rahel's (1990) definition of persistence as the constancy of a species' presence at a site over time, whereas abundance is defined to be the estimated number of adult Western Grebes at a specific site (i.e. lake). In chapter 2, I identify characteristics correlated with lakes where grebes have persisted by contrasting lakes currently occupied with the assemblage of lakes where the species has been documented during the past 40 years. This persistence problem is similar to statistics of natural selection characterizing traits of surviving individuals with those from a population prior to selection (Manly 1985). Likewise, the analysis is analogous to use/available designs in the estimation of resource selection functions (Johnson et al. 2006).

A limitation of such an analysis of persistence is imperfect species detection during surveying. Considering detection error has become an important component of any study incorporating presence/absence data (MacKenzie and Kendall 2002; Gu and Swihart 2004; Royle et al. 2005; MacKenzie 2006; Pagano and Arnold 2009). Ignoring this issue may contribute to an erroneous model if detection error is relevant but not incorporated (MacKenzie 2006). Therefore, I designed my sampling to measure detection probability so that it can be integrated into models of persistence.

I also explore habitat relationships based on estimates of abundance. In chapter 3, I compare Western Grebe abundance to the probability of persistence and use an ordinal regression model to explore habitat correlations with abundance. The importance of the relationship between persistence and abundance is illustrated with the small-population paradigm, which states that small populations are less likely to persist over time (Caughley 1994). Considering both persistence and abundance can identify habitat features correlated with persistence of Western Grebes on a particular lake, and those habitat features likely to be found where there is a large breeding colony or foraging population. Uncovering these relationships in Alberta can have larger implications for the species as a whole, because the province supports such a sizable portion of the world's Western Grebes.

I plan to submit the results from chapter 2 and chapter 3 to peer-reviewed conservation biology journals, while my 4th chapter has been published as a popular article (Erickson and Boyce 2010) and includes general conclusions and management recommendations based on my findings about persistence and abundance of the Western Grebe in Alberta.

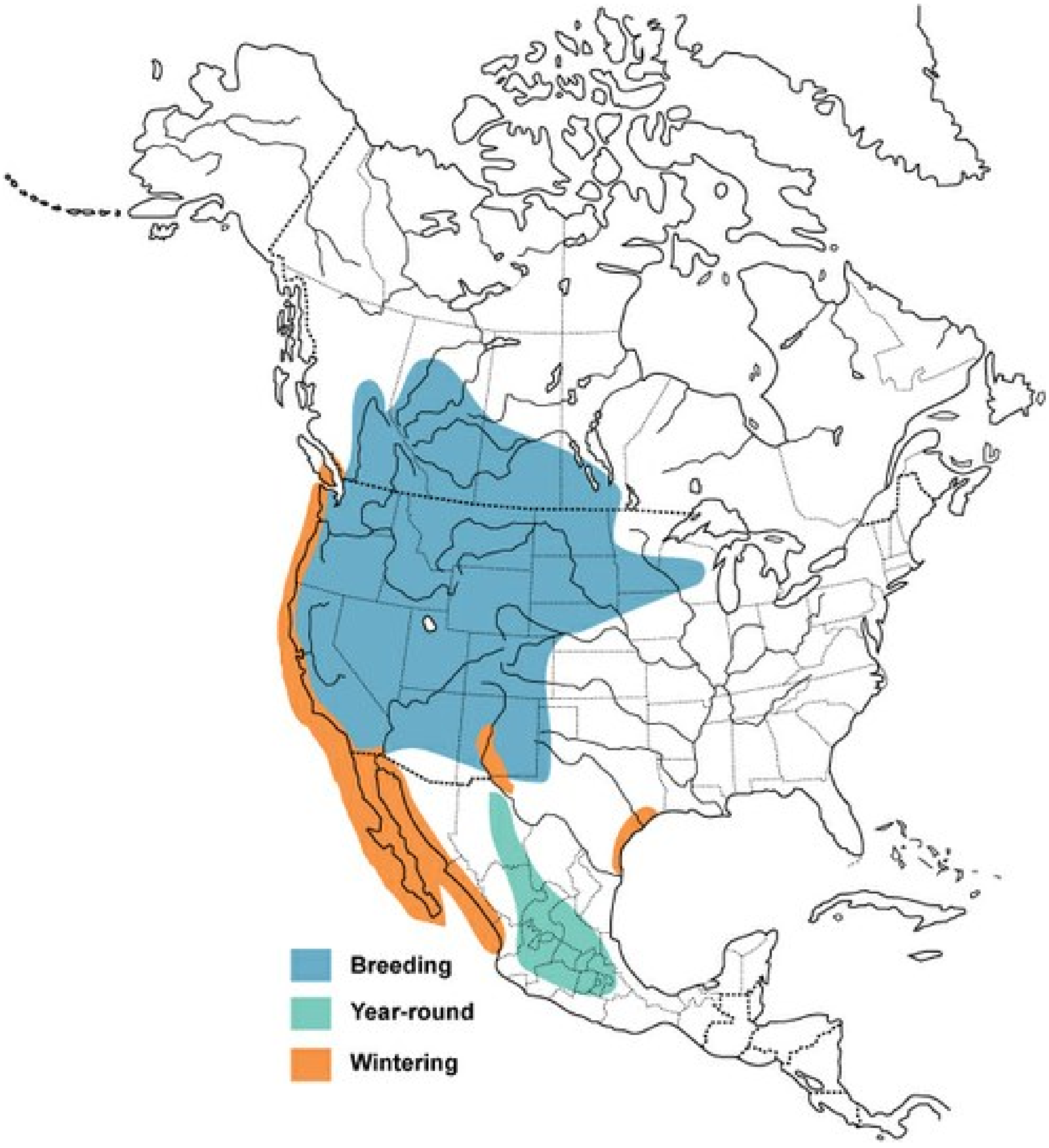

Figure 1.1: Breeding and wintering range of the Western Grebe. (Map used with permission from Birds of North America Online http://bna.birds.cornell.edu/bna maintained by the Cornell Lab of Ornithology).

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CHAPTER 2

MODELLING POPULATION PERSISTENCE: WESTERN GREBES IN ALBERTA, CANADA

INTRODUCTION:

The primary objective of most conservation programs for threatened and endangered species is to ensure population persistence. Persistence can be defined as constancy in the presence of a species at a specific temporal or spatial scale over a period of time (Rahel 1990). By monitoring multiple populations of a species through time, we can expect to unravel factors contributing to the persistence of that species.

Unlike occupancy modeling, which involves contrasting currently occupied locations with randomly selected unoccupied locations (MacKenzie et al. 2006), estimating persistence involves comparing a species' current distribution to its known former distribution, where the current distribution of occupied sites is a sub-set of the species' original distribution of once occupied sites. Thus, modelling persistence is analogous to modelling natural selection (Manly 1985), or resource selection based on weighted distributions in a use-availability design (Johnson et al. 2006; Lele 2009). However, whereas resource selection functions serve as an index of habitat selection, selection is not implied in persistence models. Instead, persistence modelling determines what habitat factors are correlated with the sites at which a species has persisted, and therefore which sites might serve as conservation targets.

Persistence has had important implications on the effects of land-cover change and human activity on various plant (Randin et al. 2009) and butterfly (Lutolf et al. 2009) species. Because land-cover change and human activity often equate to habitat degradation—the number one threat to endangered bird species in Canada (Venter et al. 2006), and threatened bird species worldwide (Stattersfield and Capper 2000), these factors may also affect the persistence of avian species, including the Western Grebe (*Aechmophorus occidentalis*). This migratory waterbird occurs only in North America (Storer and Nuechterlein 1992) and has experienced extirpations of many of its breeding populations throughout its range including some in British Columbia (Burger 1997), California (Feerer and Garrett 1977), and Alberta (Yanch 2006; Semenchuk 2007), where the species has recently been classified as a Species of Special Concern. Because Alberta supports up to 19% of the world's breeding population of around 100,000 Western Grebes (O'Donnell and Fjeldså 1997; Yanch 2006), decreased persistence in this province alone might have drastic consequences for the species as a whole.

Identifying management options to check this decline requires knowledge of habitat factors and lake characteristics affecting the species' persistence on certain lakes. Known elements affecting the occurrence (i.e., occupancy, presence) of breeding grebes on a lake include protection from predation and anthropogenic disturbance, stable water levels, protection from wind, ample water depth around and within the colony, open-water access and prey availability, and an ice-free period to allow successful nesting (Forbes 1984). Other research on the Western Grebe in Alberta has found that the species is more likely to occur on large lakes and less likely to occur on marsh-type (i.e. < 3m deep with consistent marsh-like attributes) lakes and waterbodies surrounded by boreal forest vegetation (Found et al. 2008).

In addition to the influence of a lake's habitat on the occurrence of Western Grebes, human activity might play a role. Several studies address detrimental effects of human disturbance, such as human visitation and recreational activity, to colonial nesting waterbirds (Duffy 1979; Burger 1998; Carney and Sydeman 1999). Investigating lakes with a range of recreational activity and shoreline development can give insights as to how anthropogenic activity relates to the species' persistence in Alberta.

Like other colonial waterbirds that exhibit site tenacity (Bongiorno 1970; Southern 1977), Western Grebes tend to occupy the same breeding lakes year after year as well as the same nesting area within a lake. Alberta's Cold Lake colony has been returning to Centre Bay for over 30 years, according to historical reports from the late 1970's along with more recent waterbird surveys (Kristensen and Nordstrom 1979; Found and Hubbs 2004). The breeding colony at Wabamun Lake remained in the same nesting area even after a Canadian National train derailment in 2005 spilled over 1 million litres of oil near the shore, most of which polluted the lake (Kemper et al. 2008). Knowledge of these sites and specific characteristics that can affect grebe persistence (i.e., type and density of vegetation, potential disturbance) will aid in protecting key features of Western Grebe habitats.

Detection error is inherent in characterizing a species' current distribution when using presence/absence surveys, although many studies using presence/absence data fail to account for variation in detection. While a false presence (i.e., misidentification of a species) can be controlled by using proper study design and effective observer training, false absences (i.e., the researcher fails to detect the species at the site of interest when it is indeed present) remain an unavoidable issue (MacKenzie 2005a; MacKenzie 2005b). Ignoring detection variation can lead to biased parameter estimates (Gu and Swihart 2004; MacKenzie 2005b; MacKenzie et al. 2006), therefore, detection probability is an essential source of variation to consider in modelling persistence.

The purpose of this chapter is to 1) identify factors that affect detection of the Western Grebe, and 2) identify habitat factors correlated with the persistence of the Western Grebe on a waterbody while incorporating detection error. Using data on habitat and anthropogenic characteristics from several natural regions of the province, while examining both currently and historically occupied lakes, can give insights on the factors contributing to grebe persistence on some lakes and extirpation on others.

METHODS:

Overview

I surveyed 43 lakes in the Boreal Forest (n=34), Central Parkland (n=6), and Grassland (n=3) regions of Alberta (Fig 2.1) up to 3 times during the summer of 2008 for the presence of Western Grebes, and in the summer of 2009 to document habitat and other lake characteristics. Western Grebes originally occupied all 43 lakes within the past 40 years, with 21 of those lakes supporting known breeding populations of grebes (Appendix A). Lakes are considered "breeding" lakes if either nests or young are present. I modelled persistence using a logistic discriminant function to contrast the 2 overlapping distributions of currently occupied versus historically occupied lakes, while incorporating detection probability. Analyses were conducted using Stata 10.0 (StataCorp 2007) and PRESENCE 2.4 (Hines 2006).

Study Area

The northern extent of the Western Grebes' geographic range extends into the Boreal Forest region of Alberta. The Boreal Forest occupies most of the northern portion of the province, with elevation ranging from 150m to over 1100m (Natural Regions Committee 2006). The vegetation is dominated by trembling aspen (*Populus tremuloides*) and balsam poplar (*Populus balsamifera*), as well as white spruce (*Picea glauca*), black spruce (*Picea mariana*), and jack pine (*Pinus banksiana*). Black spruce and sedge (e.g. *Carex aquatilis*) fens make up most of the wetland areas (NRC 2006). Wetlands make up 35-45% of this region and include some of Alberta's largest lakes, such as Lesser Slave Lake, Utikuma Lake, and Lac la Biche.

The Central Parkland Region in east-central Alberta serves as a transition zone for the Boreal Forest to the north and west, and the Grassland Region to the south. Trembling aspen, balsam poplar, and willow (*Salix* spp.) dominate the northern part of this region, with grasslands in the south. Much of this area has been cultivated, with wetlands occupying less than 10% of the landscape (NRC 2006). This is the most populated area of the province, including the cities of Edmonton, Red Deer, and part of Calgary. The elevation ranges from 500m to 1250m.

The Grassland Region, found in the southern part of the province, is the driest region in Alberta. A mix of cultivated land and native grassland, the area's dominant native vegetation includes porcupine grass (*Stipa spartea*) and western wheatgrass (*Agropyron smithii*). Other grasses include Parry oatgrass (*Danthonia parryi*) and a variety of fescue (*Festuca* spp.) (NRC 2006). Elevation ranges from 550m to 1500m. Lakes are generally shallow and occur in less than 2% of this region (NRC 2006). Study lakes in the Grassland region are surrounded predominantly by cultivated farmland or prairie.

Lakes in all regions ranged from limited water access (no launch, access from private property only or by a small trail) to full access (well-maintained public boat launches and several private access points). Generally, the level of recreational activity and lakeshore development mirrored the availability of lake access.

Presence-absence surveys for the Western Grebe

Presence-absence surveys were conducted from late May through late August 2008 by surface (boat, kayak, or spotting scope) or air (fixed-wing or helicopter surveys) on lakes where Western Grebes were known to have occurred during the past 40 years (See Appendix B for specific survey dates and methods). Lakes were stratified by size to adjust effort for surveying. Small lakes ($< 5\text{km}^2$) could be surveyed by spotting scope or kayak, while medium ($5\text{-}50\text{km}^2$) or large ($> 50\text{km}^2$) lakes required motor-powered watercraft. To ensure consistency between this and previous Western Grebe monitoring data, ground surveys followed techniques outlined by Hanus et al. (2002) for both spotting scope surveys and shoreline surveys, and aerial surveys followed the protocol outlined by Morris (2006).

I conducted spotting scope surveys on small lakes where ample spotting areas were available. These surveys were conducted only when conditions were too poor for kayaks (i.e., strong winds) or when there was limited staff support. A Pentax spotting scope (60X power) was set on a tri-pod at various points around the lake, and the area was scanned using fixed points on the opposite shoreline as start/stop points at which to begin/end the next survey point. The entire lake was surveyed in this manner.

Shoreline surveys were conducted from a kayak (for smaller lakes), a 5m square-stern canoe with 4.5 hp motor, or a boat with at least a 25 hp outboard motor. We followed the shoreline (20-200m out) depending on water depth and visibility, while scanning both between the shore and lake, as well as to the middle of the lake

Lakes were considered “occupied” if Western Grebes were seen or heard during the survey period. The entire lake was surveyed to obtain a complete count of all Western Grebes on the lake during that survey. The number, group size, and other characteristics of the birds were recorded.

Using a standard detectability sampling scheme where *n* lakes are surveyed *K* times (MacKenzie et al. 2006), lakes were surveyed up to 3 times during the 2008 field season. Fewer surveys are needed when occupancy and detection probabilities are high, and 3 surveys is usually considered the minimum number of repeat visits for a study design where detectability is estimated (MacKenzie et al. 2006). Three surveys were considered sufficient for this study due to the gregarious nature and conspicuous behaviour of the Western Grebe. Four assumptions proposed by MacKenzie et al. (2006) were considered when designing this presence/absence/detectability study:

1) Survey units were closed to changes in occupancy, i.e., no immigration/emigration during the survey season.

Western Grebes initiate moult and tend not to fly once they are established on a lake during their breeding season (Nuechterlein 1982; Piersma 1988), therefore it was assumed that sites were closed to movement during the time of surveying (May-August).

2) The probability of occupancy was constant across sites (or was modelled)
3) The probability of detection was constant across sites (or was modelled)

Covariates for detection (i.e., date of survey) and occupancy (i.e., lake and vegetation characteristics) addressed assumptions 2 and 3.

4) Detection of grebes at a site was independent of that site's detection history.

Observers often differed from survey to survey to reduce bias associated with observer skill, detection, and detection history.

Habitat surveys

I characterized each study lake's shoreline in terms of emergent and shoreline vegetation, as well as cottage and other shoreline development (i.e., campgrounds, man-made beaches, etc.). Surveys were conducted from the water, 20 to 400m from shoreline, depending on water depth and other factors like wind and visibility. I estimated the density and continuity of vegetation and development types on a scale of 1-5, with 1 denoting 1-5% continuity or density, 2: 6-25%, 3: 26-50%, 4: 51-75%, 5: >100% (modified from Purdy et al. 1983). Emergent vegetation was identified to species and included cattail (*Typha* spp.), common reed grass (*Phragmites australis*), and bulrush (*Scirpus lacustris*), all known to provide nesting habitats for Western Grebes. Locations of shoreline variables and point features such as beaver lodges and public boat launches were marked with a Garmin etrex Legend Hcx handheld GPS unit. Details of field data were recorded orally on a hand-held Olympus digital voice recorder, and later transcribed.

I created a recreational-activity index for each lake based on a combination of anthropogenic factors. Lakes had low or high recreational activity depending on the number of boat launches (0-3 or >4), proportion of shoreline developed (0-15% or >15%), and observations of boating and other recreational activity on the lake during the field season.

Geographical Information System (GIS)

In the geographical information system (GIS) ArcMap (ESRI 2008), I digitized 40 study lakes using a combination of georeferenced aerial photography and satellite imagery as a reference for shoreline. An existing GIS layer of Alberta's lakes obtained from ASRD was used to map the shoreline perimeter of the remaining three lakes (Cold Lake, Lac la Biche, Winefred Lake). Alberta images were obtained from ASRD, and Saskatchewan images (for Cold Lake) were purchased from Information Services Corporation (ISC) Geomatics Distribution Center in Regina, Saskatchewan. In the case of a choice between resolution and age of photo, resolution took precedence. Imagery age ranged from 1999 to 2008.

I digitized shoreline development, emergent vegetation, and point features (lake access points, beaver lodges, etc.) using field data and aerial photography (Fig 2.2). A 500m buffer surrounding the lake was surveyed for additional human development and vegetative features, consistent with the Western Grebe habitat modelling by Found et al. (2008). Development was digitized within this buffered zone using field data and aerial photography, while terrestrial vegetation and human land use was quantified from an existing GIS land-cover classification raster layer (Agri-Environment Services Branch, Agriculture and Agri-Food Canada 2008) (Fig. 2.2).

In the GIS, I calculated several emergent vegetation and development variables as well as lake area and perimeter. Bulrush was evaluated in the “emergent vegetation” variable as well as separately, due to Western Grebe preference for this species (Nuechterlein 1975).

Additional variables

Other variables deemed to be important to Western Grebe detectability and persistence (as noted in previous literature) were obtained from various sources, including Environment Canada, Alberta Environment, and ASRD. Nineteen variables were collected/generated for analysis, and categorized as lake, vegetation, buffer, or anthropogenic (Table 2.1).

Persistence models

Variable selection

I first conducted a univariate analysis estimating the logistic discriminant with logistic regression software (see Johnson et al. 2006) to evaluate each variable’s contribution to Western Grebe persistence. Variables were log-transformed if necessary to obtain approximate linearity in the logit (Hosmer and Lemeshow 2000; Vittinghoff et al. 2005). All remaining predictor variables were examined for multicollinearity. If variables were highly correlated ($|r| > 0.65$), I retained the variable with the best predictive ability according to the univariate analysis (Table 2.2).

General persistence model creation and selection

I estimated a model to assess Western Grebe persistence using the exponential form of a logistic discriminant:

$$W(x) = \exp(\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n)$$

where *W*(x) is relative to the probability of persistence, β_o, $\beta_1 \ldots \beta_n$ are coefficients estimated from the data, and $x_1, x_2, \ldots, x_n$ are the values of the independent predictor variables.

I developed 13 *a priori* models for which I estimated the logistic discriminant function to assess persistence, independent of detection (Table 2.3). Model selection used AICc for small sample size, an information-theoretic approach that maximizes the variation explained by a model while penalizing for the number of parameters in that model (Burnham and Anderson 2002). Models with lower AICc values are considered “better” explanations of the data relative to other models in the set. Models with ΔAICc < 2 (as compared to the best model) are considered to have similar levels of support, and may include ΔAICc up to 4 if the models are nested and successively differ by only one parameter (Burnham and Anderson 2002).

I used the program PRESENCE 2.4 to compare the top four persistence models from Stata 10.0 while including the effect of detection error with the variables *PropShoreRush* and *Date* (see Table 2.1 for variable definitions). Emergent vegetation, especially bulrush, along the shoreline may provide cover for grebes, thus affecting the observer’s ability to see the birds. The date of survey may affect detection probability due to the birds’ varied use of the lake (i.e., open water foraging vs. use of the reed beds), especially on breeding lakes. Fifteen models were compared, using combinations of constant and varied detection probabilities (Table 2.4).

Because I evaluated multiple models using AICc, I assessed the most global model (that with the greatest number of parameters) for lack of fit. If the global model adequately fits the data, then more parsimonious models also should perform well (Burnham and Anderson 2002; MacKenzie et al. 2006). A poor-fitting model would require adjustments to model selection procedures and standard error estimates.

RESULTS:

Presence-Absence surveys

Of my 43 study lakes that historically supported Western Grebes, I surveyed 31 lakes 3 times, 2 lakes twice, and 10 lakes once during the summer of 2008. Detection history varied from lake to lake, with some lakes always absent, some always present, and some with both detections and non-detections (Table 2.5). Twenty-seven lakes were occupied during at least one survey, resulting in a naïve persistence estimate of 0.63. Evidence of breeding (presence of nests or young) was noted on ten lakes (Appendix A), with established nesting colonies on eight of those ten.

Persistence models

Variable selection

I retained six of the original 19 variables after univariate analyses and a correlation assessment and used them to construct 13 *a priori* models, including a null model (Table 2.2).

Model creation and selection

The global model had the lowest AICc score and highest model weight (w_i = 0.66) of all 13 models. This was followed by three models with ΔAICc < 5 and a combination of *PropShoreRush*, *PropForest500m*, and ln*PropDevelop500m* (Models 5, 11, 7) (Table 2.6). Neither the number of fish species in a lake nor shoreline length were top-performing variables in predicting overall Western Grebe persistence.

After evaluating the top 4 models in PRESENCE 2.4 with the inclusion of detection variables, there was a shift in the top-performing models as compared to the results without detection error (Table 2.7). The global model (A) resulted in overdispersion (c-hat = 3.83, $P = 0.009$) even without the inclusion of detection variables. There also was evidence of non-convergence and inflated standard errors for this model; therefore, it was not evaluated with additional detection terms.

The alternative global model (I) [ψ*(PropShoreRush + PropForest500m* + ln*PropDevelop500m)* p*(PropShoreRush + date)*] showed good fit to the data (c-hat = 0.97, $P = 0.48$), suggesting that the more parsimonious alternative models also would adequately explain the data.

There was no clear top-performing model because the top five models in this set all had ΔAICc < 2 and AICc $w_i > 0.5$, suggesting similar support (Table 2.7). The models containing *PropShoreRush* as a detection covariate performed better than those with *Date* or *Date+PropShoreRush*. However, models with constant detection performed slightly better than their counterparts containing *PropShoreRush* as a detection covariate, although the ΔAICc values were < 1 in each pair's case. Overall, the amount of development in a 500m buffer around the lake as well as the amount of bulrush along the shoreline were positively related, while the amount of forest in a 500m buffer was inversely related to Western Grebe persistence. Shoreline bulrush negatively affected detection probability (Table 2.8).

Neither shoreline length nor the number of fish species significantly predicted grebe persistence. However, lakes with both grebe persistence and heavy human development had on average, a greater shoreline perimeter (66.6km ± 11.9SE vs. 38.6km ± 6.2SE) and more fish species (6.9 ± 0.98SE vs. 4.7 ± 0.81SE) compared to lakes that no longer supported grebes.

DISCUSSION:

According to the overall persistence models, *Date* did not contribute appreciably to variation in detection probability, nor were *ShoreLength* and *#FishSpp* included in any top models. *PropShoreRush* emerged as a possible source of detection error, while *PropForest500m*, *PropShoreRush*, and ln*PropDevelop500m* were top-performing variables relative to Western Grebe persistence. Survey date did not contribute strongly to variation in detection probability, suggesting that the time of season when surveys are conducted for Western Grebes does not affect the observer's ability to detect the bird.

The number of fish species did not emerge as an important factor for grebe persistence. However, all study lakes (but one) were currently fish bearing, suggesting that the species richness of fish might not significantly affect persistence as long as a fish prey base exists. Further study on the nature of the fish community to both breeding and non-breeding grebes should include a greater number of non-fish bearing lakes to elucidate a true relationship between the presence of fish and the presence of grebes. Examining the relative abundance of specific fish species also might provide a better idea of the role of fish in Western Grebe persistence.

Persistence models containing shoreline length tended towards non-convergence and/or overdispersion, therefore this variable was not included in the final models. However, all major breeding colonies occurred on lakes with a shoreline of at least 40.9 km; therefore, larger lakes might provide conditions allowing persistence, at least by breeding grebes. Non-breeding grebes (i.e., no evidence of nests or young) were documented on even the smallest study lakes (e.g., Angling Lake, 9km shoreline).

The amount of shoreline bulrush negatively affected detection probability. However, the effect of this variable was not highly significant, suggesting that current survey methods for Western Grebes are sufficient in detecting the species.

In all top models that included *PropForest500m*, the variable was inversely associated with Western Grebe persistence. This is consistent with Found et al. (2008), who found a negative relationship between the occurrence of Western Grebes and a forested buffer. They propose this might be due to an inverse association between high amounts of emergent vegetation at a lake (a necessary component for breeding grebes) and less forested area in the buffer zone. The relationship may also reflect the fact that the majority of the Western Grebe's North American range occurs in drier grassland or sagebrush regions (Storer and Nuechterlein 1992), whereas forested lakes are concentrated in the extreme northern boundary of the species' range and might be marginal habitat. Nevertheless, periphery populations should not be ignored in a conservation context, because range contraction is not necessarily inevitable in a declining species (Channell and Lomolino 2000). Western Grebe persistence on select lakes in the boreal forest region is still an important management consideration because many of the occupied boreal lakes support some of the largest colonies in Alberta.

Bulrush is used for nest anchoring and construction (Nuechterlein 1975; Riske 1976; Short 1984; Storer and Nuechterlein 1992), and therefore serves as an important habitat component. Ample emergent vegetation is needed to establish a nesting colony and serves as protection from wave action or other disturbances

(Allen et al. 2008). Damage to or elimination of this vegetation along the shoreline (e.g., for development) reduces the availability of colony locations and nesting material. Snowmobiling in reed beds and bulrush stands during the winter months destroys the old growth, rendering it useless for the birds when they return to breed the following spring (Berg et al. 2004).

The variable ln*PropDevelop500m* was positively related to the persistence of Western Grebes. Similarly, Found et al. (2008) found that the occurrence of Western Grebes in the northeastern boreal region of Alberta was positively associated with a high level of recreational activity. They attributed this relationship to possible habituation (also see Newbrey et al. 2005) as well as a tendency for humans to select lakes with the same characteristics that grebes prefer (i.e., deep water, presence of fish, medium to large lakes). For example, although grebes persisted on heavily developed lakes in Alberta, these lakes also had a larger shoreline perimeter and a greater number of fish species. Therefore, it is difficult to separate grebe persistence on lakes with human development from human selection of grebe habitat.

Another possible explanation for grebe persistence on developed lakes might be a lag effect of development on grebes. This pattern may not be apparent immediately or if only evaluating persistence relationships, but may emerge when examining the rate of increased development against a decrease in the local abundance of Western Grebes. For instance, 3 major Western Grebe breeding lakes in the Stony Plain region—Isle Lake, Wabamun Lake, and Lac Ste Anne—have high levels of development and a consistent decrease in the number of breeding Western Grebes over the past 9 years of monitoring (Yanch 2006). This may be due to habitat loss associated with lakeshore development, because developed shorelines have decreased emergent vegetative cover as compared to undeveloped shorelines (Radomski and Goeman 2001). The rate of habitat change is another important factor to consider, because this can affect persistence independently from the altered habitat (Lutolf et al. 2009). Therefore, lakes with higher rates of development may have more drastic effects on grebe persistence relative to those with slower rates of lakeshore alteration, exacerbating the effects of habitat loss on Western Grebe populations.

Water-level fluctuation is another important factor to consider, because this can alter the availability of habitat for Western Grebes (Parmelee and Parmelee 1997). For example, the water level of Muriel Lake in northeastern Alberta—which once supported over 400 breeding grebes (Yanch 2006)—has dropped over 3 metres during the past 35 years. Currently, only 40 Western Grebes now persist on the lake with no evidence of a breeding colony. Western Grebes might be able to delay nesting until water levels are high enough to support ample emergent vegetation on sites where they occur year-round (Parmelee and Parmelee 1997), but this is not feasible on their northern breeding grounds, where annual freeze-up determines the length of the breeding season.

Other causes of a low probability of persistence might involve direct disturbance. Common forms of nest-site disturbance during the breeding season include waves and wakes from boats and personal watercraft that may swamp nests. Boating and other recreational activity near the colony may provoke adults to make rushed exits, leaving the eggs vulnerable to exposure and accessible to predators such as Ring-Billed Gulls (*Larus delawarensis*), Black-billed Magpies (*Pica pica*), and American Crows (*Corvus brachyrhynchos*). Adults may abandon unhatched eggs if disturbed during the hatching period (Storer and Nuechterlein 1992). Re-nesting may be possible (Lindvall and Low 1982), but recruitment success is not guaranteed if chicks do not fledge early enough for migration. Consequently, disturbance can negatively affect already low recruitment rates and may contribute to decreased persistence.

CONCLUSION

For a Species of Special Concern like the Western Grebe, modelling persistence rather than occupancy illustrates the type of habitats supporting the current spatial distribution of a species relative to its historical distribution. With this approach, we gain an idea of what lakes contain the habitat factors that are correlated with the probability of Western Grebe persistence, thereby serving as conservation targets.

The persistence of both breeding and non-breeding populations of grebes is positively associated with the amount of shoreline bulrush and development in a 500m buffer surrounding the lake, and inversely related to forest vegetation in a 500m lake buffer. However, because grebes use the same lakes that humans use for recreation, it is essential to minimize disturbance to the birds and their habitats. Other studies have recommended implementing a buffer zone around breeding colonies during the breeding season (Yanch 2006). This would lessen the effects of wakes created by motor boats, and eliminate human disturbance from non-powered craft. As grebes frequently return to the same area year after year, I suggest this buffer zone remain during the winter months to keep the nest site intact. Prohibiting activities that might scour or damage old-growth emergent vegetation (e.g., snowmobiling over the vegetation) will ensure vegetation is available the following spring for colony establishment.

Bulrushes and other natural emergent vegetation should remain intact, and not be removed for cottage or shoreline development. Not only will this benefit grebes, but other colonial waterbirds that use emergent vegetation for nesting (e.g., Red-necked Grebes (*Podiceps grisegena*), Forster's Tern (*Sterna forsteri*), Franklin's Gull (*Larus pipixcan*)) and fish species that use aquatic and emergent vegetation for spawning and foraging such as northern pike (*Esox lucius*). Emergent vegetation is also a positive indicator of a healthy aquatic environment, serving as habitat for species like those listed above while reducing shoreline erosion, and providing a more natural, esthetically pleasing shoreline (Radomski and Goeman 2001).

Other detrimental effects to grebes and their habitats such as predation or nest damage from storms are not as easily controlled through management practices. Readily implemented, practical solutions like those suggested above are essential to maintain ample nesting habitat, reduce disturbance, and promote persistence of Western Grebes. Because Alberta's Western Grebes constitute up to 19% of the world's breeding population, the persistence of the species in this province is especially important in a global context.

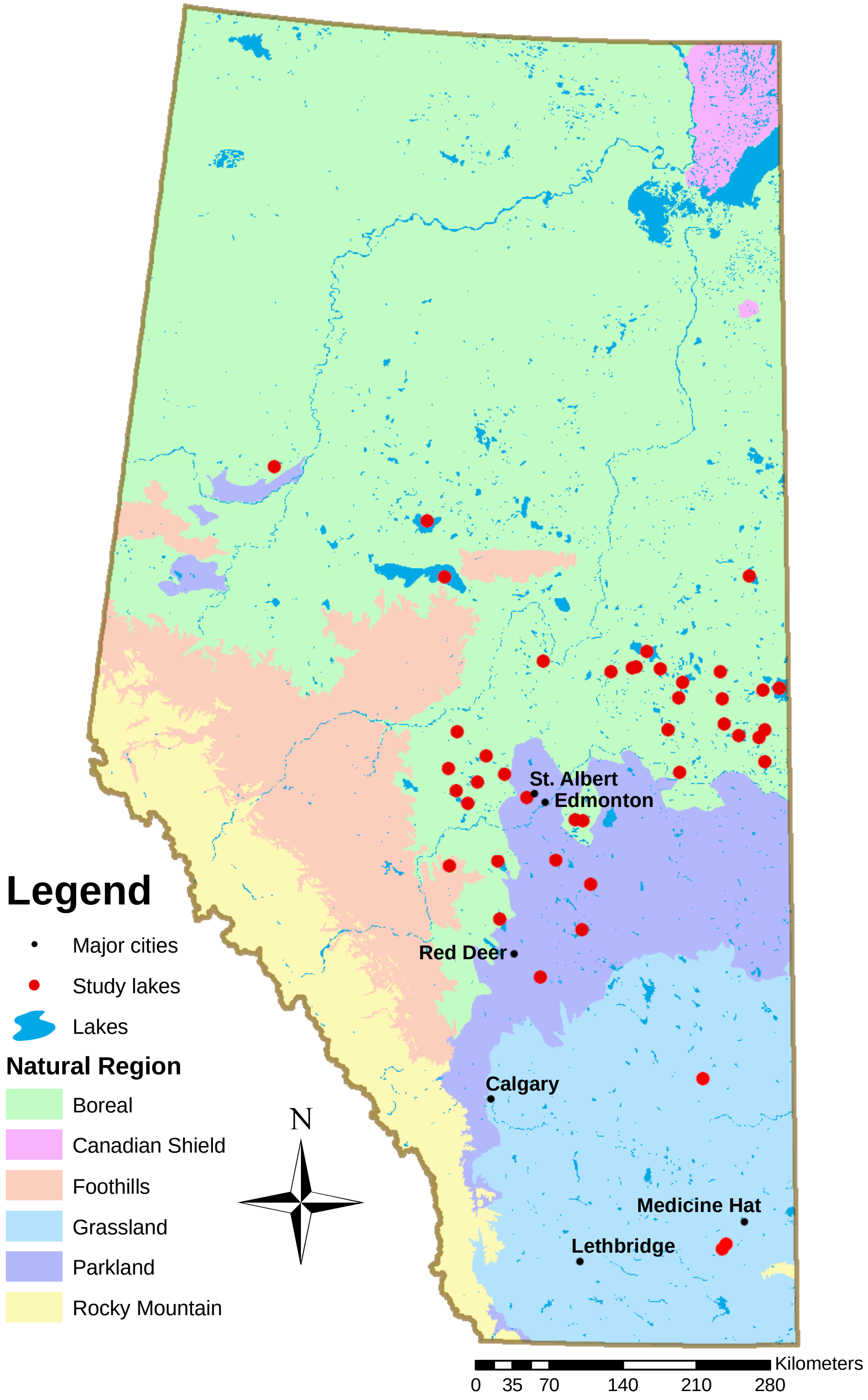

Figure 2.1: Map of study lakes (n = 43) in Alberta, Canada. Lake names and locations are found in Appendix A.

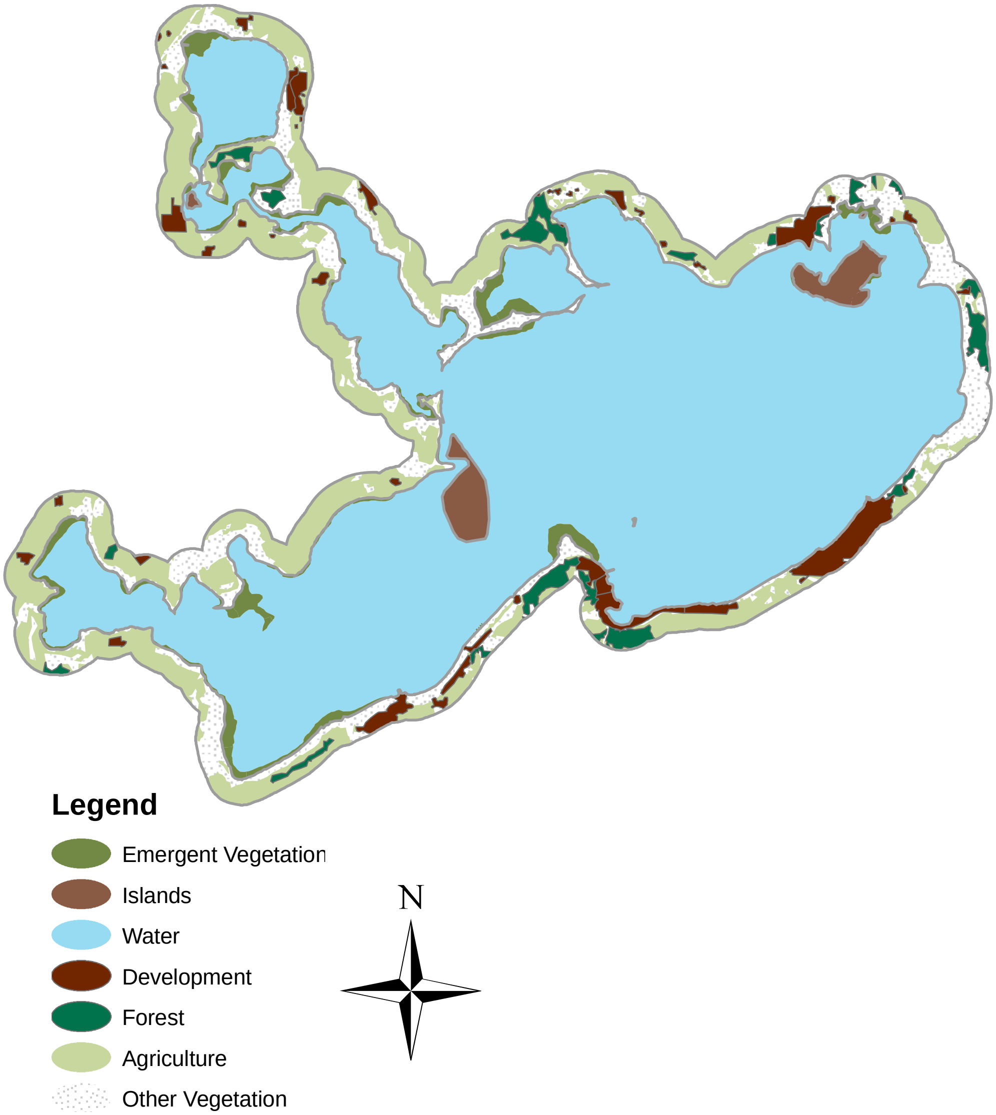

Figure 2.2: Example of digitized lake used to quantify anthropogenic, lake, and vegetation variables. Variables were quantified within a 500m buffer surrounding the lake.

Table 2.1: Site covariates collected/generated from the 2008 field season to determine detection and persistence of the Western Grebe in Alberta.

Variable Name	Description	Units	Category	Source
ln*PropDevelop500m*	Proportion of human development in 500m buffer surrounding lake ($\log_e$ transformed)	percent	Buffer_anthropogenic	1, 2, 3
PropCon500m	Proportion of coniferous forest in 500m buffer surrounding lake	percent	Buffer_vegetation	3
PropDec500m	Proportion of deciduous forest in 500m buffer surrounding lake	percent	Buffer_vegetation	3
PropForest500m	Proportion of total forest in 500m buffer surrounding lake	percent	Buffer_vegetation	3
PropAg500m	Proportion of agriculture in 500m buffer surrounding lake	percent	Buffer_anthropogenic	3
SurfaceArea	Lake surface area	km^2	Lake	2,3
MaxDepth	Maximum lake depth	m	Lake	4
MeanDepth	Mean lake depth	m	Lake	4
ShoreLength	Length of lake perimeter	km	Lake	2,3
PropShoreDevelop	Proportion of human development along shoreline	percent	Anthropogenic	1,3
RecIndex	Recreational index of lake	0=low; 1=hi	Anthropogenic	1

(cont.)

Table 2.1: ***(cont.)***

Variable Name	**Description**	**Units**	**Category**	**Source**
PropShoreEveg	Proportion of emergent vegetation along shoreline	percent	vegetation	1,3
PropLakeEveg	Proportion of emergent vegetation in lake	percent	vegetation	1,3
PropLakeRush	Proportion of bulrush (*Scirpus lacustris*) in lake	percent	vegetation	1,3
PropShoreRush	Proportion of bulrush (*Scirpus lacustris*) along shoreline	percent	vegetation	1,3
PropShoreRush4_5	Proportion of bulrush (*Scirpus lacustris*) along shoreline with a continuity and density rating of 4 or 5	percent	vegetation	1,3
PropLakeRush4_5	Proportion of bulrush (*Scirpus lacustris*) in lake with a continuity and density rating of 4 or 5	percent	vegetation	1,3
#FishSpp.	Number of different fish species in lake	Integer value	Lake	5
Date	Julian date of survey	Integer value	Date	1

Sources: [1]Field [2]Aerial Photographs [3]GIS [4]multiple sources in order of use: Mitchell and Prepas (1990), Energy Resources Conservation Board (2008), Angler’s Atlas, Alberta Sustainable Resource Development Fish Management Information System (FMIS) reports (2008), Rawles (2007), Purdy et al. (1983), MacNeil (1980), Chipeniuk (1975) Anderson (pers. comm.),[5]ASRD FMIS (2008)

Table 2.2: Reduced list of habitat variables (and their minimum, maximum, and mean values) used to model persistence of Western Grebes. Descriptions of variables are found in Table 2.1.

Variable Name	**Units**	**Min. Value**	**Max. Value**	**Mean Value**
ln*PropDevelop500m*	percent	-6.59	-1.32	-3.22
PropForest500m	percent	0	0.8	0.33
ShoreLength	km	5.99	297.29	56.17
PropShoreRush	percent	0	0.78	0.21
#FishSpp.	Integer value	0	19.0	6.07
Date	Integer value	145	240	N/A

Table 2.3: Suite of *a priori* models used to model persistence. Definitions of variables are found in Table 2.1.

Model #	**Model Categories/variables**
	Lake
1	*ShoreLength*
2	*#FishSpp*
3	*ShoreLength* + *#FishSpp*
	Vegetation
4	*PropShoreRush*
	Buffer
5	ln*PropDevelop500m*
6	*PropForest500m*
7	ln*PropDevelop500m* + *PropForest500m*
	Lake + Vegetation
8	*ShoreLength* + *#FishSpp* + *PropShoreRush*
	Lake + Buffer
9	*ShoreLength* + *#FishSpp* + ln*PropDevelop500m*
10	*ShoreLength* + *#FishSpp* + *PropForest500m*
	Vegetation + Buffer
11	*PropShoreRush* + *PropForest500m* + ln*PropDevelop500m*
	Global
12	*ShoreLength* + *#FishSpp* + *PropShoreRush* + *PropForest500m* + ln*PropDevelop500m*
	Null
13	(no variables)

Table 2.4: Suite of *a priori* models used to assess detection error. Ψ (“variable”) are variables affecting current occupancy; p(“variable”) are variables affecting detection. (.) denotes constant occupancy and/or detection probability. Full definitions of variables are found in Table 2.1.

Model letter	Variables
	Global
A	Ψ (*ShoreLength* + *#FishSpp* + *PropShoreRush* + *PropForest500m* + ln*PropDevelop500m*) p(.)
	Develop
B	Ψ (ln*PropDevelop500m*) p(.)
C	Ψ (ln*PropDevelop500m)* p*(PropShoreRush*)
D	Ψ (ln*PropDevelop500m*) p(*date*)
E	Ψ (ln*PropDevelop500m*) p(*PropShoreRush* + *date*)
	Rush + Forest + Develop
F	Ψ *(PropShoreRush* + *PropForest500m* + ln*PropDevelop500m)* p*(.)*
G	Ψ *(PropShoreRush* + *PropForest500m* + ln*PropDevelop500m)* p*(PropShoreRush)*
H	Ψ *(PropShoreRush* + *PropForest500m* + ln*PropDevelop500m)* p*(date)*
I	Ψ *(PropShoreRush* + *PropForest500m* + ln*PropDevelop500m)* p*(PropShoreRush* + *date)*
	Develop + Forest
J	Ψ *(*ln*PropDevelop500m* + *PropForest500m)* p*(.)*
K	Ψ *(*ln*PropDevelop500m* + *PropForest500m)* p*(PropShoreRush)*
L	Ψ *(*ln*PropDevelop500m* + *PropForest500m)* p*(date)*
M	Ψ *(*ln*PropDevelop500m* + *PropForest500m)* p*(PropShoreRush* + *date)*
	Constant
N	Ψ *(.)* p*(.)*
O	Ψ *(.)* p*(survey-specific)*

Table 2.5: Frequencies of detection histories for up to three surveys at each of 43 study lakes May-August 2008. A site's detection history consists of detections (1), non-detections (0). Missing observations (-) occurred when logistical limitations (weather, limited staff support, etc.) prevented surveying.

Detection History	**Frequency**
111	12
000	11
1--	5
0--	5
011	2
001	2
110	1
101	1
100	1
010	1
11-	1
10-	1

Table 2.6: AICc values (AICc) and differences from the top model (ΔAICc), model likelihoods, and model weights (w_i) for 13 *a priori* candidate models for Western Grebe persistence. *K* represents the number of model parameters. Models are ranked from lowest AICc score to highest.

Model #	***K***	**AICc**	**ΔAICc**	**Model Likelihood**	w_i
12	6	46.77	0.00	1.00	0.66
5	4	50.17	3.40	0.18	0.12
11	2	50.38	3.62	0.16	0.11
7	3	51.55	4.78	0.09	0.06
9	4	53.19	6.42	0.04	0.03
8	4	55.69	8.92	0.01	0.01
4	4	56.55	9.78	0.01	0.00
10	2	56.59	9.82	0.01	0.00
1	2	57.17	10.41	0.01	0.00
2	2	58.48	11.72	0.00	0.00
13	1	58.86	12.10	0.00	0.00
3	3	58.90	12.13	0.00	0.00
6	2	59.66	12.90	0.00	0.00

Table 2.7: AICc values (AICc) and differences from the top model (ΔAICc), model likelihoods, and model weights (w_i) for 13 a priori candidate models for Western Grebe persistence in light of detection error. *K* represents the number of model parameters. Models are ranked from lowest AICc score to highest.

Model letter	***K***	**AICc**	**ΔAICc**	**Model Likelihood**	w_i
B	3	117.79	0.00	1.00	0.19
C	4	118.30	0.51	0.77	0.15
F	5	118.50	0.71	0.70	0.14
G	6	118.96	1.17	0.56	0.11
J	4	119.17	1.38	0.50	0.09
K	5	119.84	2.05	0.36	0.07
D	4	120.15	2.36	0.31	0.06
E	5	120.69	2.90	0.23	0.05
H	6	121.08	3.29	0.19	0.04
I	7	121.57	3.78	0.15	0.03
L	5	121.67	3.88	0.14	0.03
M	6	122.36	4.57	0.10	0.02
N	2	124.42	6.63	0.04	0.01
O	4	128.64	10.85	0.00	0.00
A	7	165.3	47.51	0.00	0.00

Table 2.8: Summary of the beta coefficients (β), standard errors (SE), and upper and lower 95% confidence intervals (CI) for the most parsimonious candidate models (ΔAICc < 2) incorporating detection error. Full definitions of the variables are found in Table 2.1.

Model	**Variable**	**β**	**SE**	**95% CI**
B	Ψ	3.49	1.17	1.20, 5.79
	Ψ(ln*PropDevelop500m)*	0.86	0.32	0.22, 1.49
	p	1.36	0.32	0.72, 1.99
C	Ψ	3.44	1.12	1.24, 5.64
	Ψ(ln*PropDevelop500m*)	0.86	0.31	0.24, 1.47
	p	1.95	0.57	0.84, 3.07
	p*(PropShoreRush)*	-1.81	1.32	-4.39, 0.78
F	Ψ	3.62	1.39	0.88, 6.36
	Ψ*(*ln*PropDevelop500m)*	0.85	0.35	0.15, 1.55
	Ψ*(PropShoreRush)*	3.41	2.08	-0.66, 7.49
	Ψ*(PropForest500m)*	-2.43	2.01	-6.36, 1.51
	p	1.39	0.32	0.76, 2.02
G	Ψ	3.57	1.37	0.89, 6.25
	Ψ*(*ln*PropDevelop500m)*	0.85	0.35	0.17, 1.54
	Ψ*(PropShoreRush)*	3.56	2.09	-0.53, 7.65
	Ψ*(PropForest500m)*	-2.41	1.98	-6.29, 1.48
	p	2.01	0.56	0.91, 3.11
	p*(PropShoreRush)*	-1.94	1.31	-4.49, 0.62
J	Ψ	4.12	1.39	1.39, 6.85
	Ψ*(*ln*PropDevelop500m)*	0.86	0.34	0.20, 1.52
	Ψ*(PropForest500m)*	-1.87	1.87	-5.55, 1.79
	p	1.36	0.32	0.72, 1.99

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CHAPTER 3

ABUNDANCE RELATIVE TO THE PERSISTENCE OF WESTERN GREBES IN ALBERTA, CANADA

INTRODUCTION:

A central paradigm in conservation biology is that small populations are more vulnerable to extinction due to stochastic fluctuations (MacArthur 1972), and biological interactions in small populations can result in an extinction vortex (Gilpin and Soulé 1986). However, this small-population paradigm is largely a theoretical construct seldom examined empirically (Caughley 1994), and may not adequately describe mobile species, such as migratory birds, that can experience fluctuations in local abundance while still persisting on the landscape through recolonization. Therefore, although occupancy and persistence data provide valuable information about the local distribution of a species, they may not reflect finer-scale changes in the abundance, or, number of individuals of that species.

Alberta's Western Grebe population is an example of a potential disconnect between persistence and abundance. For instance, three major colonies of Western Grebes have experienced a 70% loss of adults over the past decade, yet grebes still have persisted on those lakes (Figure 3.1). Furthermore, although Western Grebe persistence—i.e. constancy in presence over time (Rahel 1990) has decreased, the reduction in abundance has been much more dramatic with a 37% decline in persistence as compared to a 76% decline in abundance on 43 lakes in Alberta (Yanch 2006; ASRD unpublished data). Focusing only on persistence of Western Grebes in Alberta and not abundance in this situation might not detect the extent of the population decline in the province.

Alberta is not the only area where Western Grebes are declining in abundance, although it is an important jurisdiction to study as it supports 13-19% of the world's breeding population of Western Grebes (Yanch 2006). Other breeding areas have noted decreased abundance estimates including British Columbia, where it is listed on their Red List as imperiled (Burger 1997; B.C. Conservation Data Centre 2010) and California (Feerer and Garrett 1977). On their wintering grounds, there have been declines in abundance of up to 95% in areas that once boasted some of the largest concentrations of wintering Western Grebes (Burger 1997; Puget Sound Action Team 2004).

While some studies have focused on factors correlated with occurrence of Western Grebes, including fish-bearing lakes and ice-free periods for nesting (Nuechterlein 1975; Riske 1976; Forbes 1984; Found et al. 2008), none have directly addressed the relationship between habitat and abundance. Therefore, it is important to examine abundance relative to persistence by comparing the habitat characteristics that best describe both parameters. Because habitat loss is the number one threat to the world's endangered avian species (Stattersfield and Capper 2000), exploring this relationship will facilitate better management and conservation of habitat on lakes with declining Western Grebe populations.

In chapter 2, I documented that detection error did not significantly affect estimates of the probability of Western Grebe persistence. Persistence of Western Grebes on lakes in Alberta was positively associated with the amount of shoreline bulrush (*Scirpus lacustris*), but inversely related to the amount of forested area in a 500m buffer surrounding the lake. Surprisingly, Western Grebes were more likely to have persisted on lakes that supported higher levels of anthropogenic development within the 500m buffer. However, the lakes on which grebes persisted also were large lakes with a greater number of fish species, both attractive attributes for lakeshore development.

In this chapter, I will 1) determine the extent of the relationship between Western Grebe abundance (i.e., number of adults on a lake) and persistence, and 2) determine if the same factors that affect persistence also affect abundance. If not, what combination of factors best predicts persistence and abundance? Understanding the habitat characteristics that are correlated with Western Grebe abundance will provide a better idea of what lakes are more likely to support higher numbers of grebes, and where we should focus conservation efforts to curb declines as well as to ensure population persistence.

METHODS:

Overview

During the summers of 2007 through 2009, I estimated Western Grebe abundance on 43 lakes using nest counts, brood counts, and shoreline waterbird surveys. All lakes supported grebes, either historical or currently (Appendix A). I also surveyed these lakes for emergent vegetation, human development, and other habitat characteristics. I graphically evaluated the relationship between the probability of Western Grebe persistence and abundance, and used ordered logistic regression to assess the relationship between habitat and abundance. Because detection error was not a significant factor in estimating persistence, I did not incorporate it into models of abundance.

Study Area

I conducted surveys for Western Grebe abundance and habitat variables on 43 lakes in Alberta's Boreal Forest, Central Parkland, and Grassland regions (Figure 3.2) at which the species was known to occur within the past 40 years.

The Boreal Forest region covers the northernmost part of the province, extending south of the city of Red Deer. Major vegetation includes trembling aspen (*Populus tremuloides*) and balsam poplar (*Populus balsamifera*), white spruce (*Picea glauca*), black spruce (*Picea mariana*), and jack pine (*Pinus banksiana*). Some of Alberta's largest and deepest lakes occur in this region, with 35-45% of the landscape dominated by wetlands (Natural Regions Committee 2006).

The Central Parkland region includes the most populated areas in the province, including Edmonton, Red Deer, and Calgary. Wetlands make up between 8-10% of this region (NRC 2006). The vegetation reflects a transition between the northern boreal forest and southern grasslands.

The Grassland region located in southern Alberta consists of mostly agricultural lands and native grassland including many species of fescue (*Festuca* spp.). Lakes occupy less than 2% of this region.

Abundance surveys

During the summers of 2007 through 2009, I used 1) nest counts and 2) brood counts to obtain abundance estimates on breeding lakes. Aerial surveys in early- to mid-July 2007 confirmed occurrence of breeding colonies on Lac la Biche, Moose Lake, Cold Lake, and Wabamun Lake. Shoreline waterbird surveys were used to estimate abundance of Western Grebes on non-breeding lakes.

Nest counts

To minimize disturbance, nest counts were conducted shortly after chicks had hatched and left the nesting site in late July. Observers entered the colony in chest waders or in kayaks/canoes (depending on the water level). Nests were counted on transects along the length of the colony, with two to five observers within eyesight of each other (Figure 3.3). Distance between observers varied depending on the density of nests, density and type of vegetation, as well as the number of observers; more nests, denser vegetation (i.e. *Typha* spp. or *Phragmites australis*), and fewer observers required narrower transects. Transect length extended a few metres beyond the edge of the colony to ensure it was the true end.

Nests were recorded as “Active” (intact with warm eggs), “Intact” (intact with no eggs), “Partially submerged,” or “Submerged.” Submerged nests were differentiated from muskrat platforms by the amount of vegetation underneath the nest, because Western Grebe nests are built on top of emergent vegetation. I estimated two breeding adults per nest (Hanus et al. 2002). For those lakes that did not have nest counts in 2008 or 2009 (due to logistic factors and to minimize disturbance), 2007 estimates were used. All colonies were visited in either 2008 or 2009, however, to confirm breeding activity

Brood counts

Brood counts were conducted on a subset of breeding lakes during the late summers of 2008 and 2009 to confirm the reliability of earlier nest counts as well as to document recruitment. One driver and one to two observers surveyed the lake of interest using zigzag transects across the lake, stopping at the start of each transect to count all adult and juvenile birds. Observers used binoculars to allow a safe distance between the boat and the birds. I used brood count estimates in data analysis if nest count data were not available for a particular breeding lake, or if the brood count data yielded a higher abundance estimate (See Appendix C for the year of latest abundance estimates).

Shoreline waterbird surveys

Shoreline waterbird surveys followed techniques outlined by Hanus et al. (2002) and were conducted from a kayak (for smaller lakes), a 5m square-stern canoe with 4.5 hp motor, or a boat with at least a 25 hp outboard motor. We followed the shoreline (20-200m out) depending on water depth and visibility, while scanning both between the shore and lake, as well as to the middle of the lake. The entire lake was surveyed to obtain a complete count of all Western Grebes on the lake during that survey.

Persistence-abundance relationship

Using an information-theoretic approach for model selection (Burnham and Anderson 2002), I identified the top-ranked persistence model that incorporated detection probability, and plotted the relative probability of Western Grebe persistence against estimates of abundance. I used a correlation coefficient to determine the strength of the relationship between the two parameters. Analyses were conducted in Stata 10.0 (StataCorp 2007).

Abundance models

I used ordered logistic regression to compare the relationship between Western Grebe abundance and habitat. Ordinal regression models can be used to predict abundance by comparing ranked categories of the response variable when the differences between categories are unknown, and are not necessarily equal (Guisan and Harrell 2000; Long and Freese 2006).

Maximum grebe abundance was divided into three categories (zero birds, 1-50 birds, and > 50 birds) and modeled as a function of five habitat variables (Table 3.1) that also were used to model persistence to allow comparisons between persistence and abundance. Eight of ten breeding lakes fell into the > 50 birds category. I adjusted the model structures to account for small sample size (Table 3.2). Threshold values (labeled *cut1* and *cut2* in Stata 10.0) describe the value at which a subject is classified at zero birds (values < *cut1*), 1-50 birds (values between *cut1* and *cut2*), and > 50 birds (values > *cut2*) given that the predictor values in that model are evaluated at zero (UCLA 2009). I tested for the proportional odds assumption to determine if there is a difference in the coefficients between models, while a likelihood ratio test compared each model to a null model without count predictors to test the significance of the model overall (UCLA 2009). A proportional odds ratio was used to compare the highest abundance category to the lower categories for each predictor variable (UCLA 2009). I used AICc for small sample size, an information-theoretic approach, to compare alternative models (Burnham and Anderson 2002).

RESULTS:

Abundance data

I detected Western Grebes at 27 of the 43 lakes where the species had occurred in the recent past. The estimated number of grebes on occupied lakes ranged from 1 – 2,716, with an average of 200 and a median of 11 birds; most occupied lakes had few birds, but those with large colonies tended to have 100 birds or more. All lakes with estimates > 50 adult Western Grebes had established breeding colonies (Figure 3.2).

Persistence/abundance relationship

Using the variable ln*PropDevelop500m* to estimate the probability of persistence, the relationship between Western Grebe abundance and persistence was significantly correlated ($r = 0.59$, df = 20, $P < 0.01$) (Figure 3.4), although abundance only accounted for 35% of the variance in persistence.

Abundance models

Similar to the persistence models, the most parsimonious (ΔAICc < 2) ordinal logistic regression models had habitat covariate combinations of ln*PropDevelop500m, PropShoreRush*, and *PropForest500m* (Table 3.3). Model #5 had the highest model weight ($w_i = 0.42$) while Model #11 and Model #7 had $w_i = 0.36$ and $w_i = 0.17$, respectively. All three top models were statistically significant ($P < 0.001$) according to the likelihood ratio test. *ShoreLength* and *#FishSpp* were not in any top models.

In all three models, ln*PropDevelop500m* had a positively significant ($P < 0.001$) relationship with Western Grebe abundance (Table 3.3). *PropShoreRush* and *PropForest500m* had positive and negative relationships coefficients, respectively, although neither variable was statistically significant ($P = 0.152$ and $P = 0.428$, respectively) (Table 3.4).

Lakes with increased development in a 500m buffer were roughly 2.8 times more likely to have over 50 Western Grebes versus fewer than 50 birds or no birds at all (Table 3.5.) The proportion of shoreline covered by bulrush also favored higher-ranked categories (OR = 6.718) while an increased amount of forest in a 500m buffer favored fewer birds or no birds at all (OR = 0.297) (Table 3.5).

Lakes in the high (> 50 birds) category had a greater species richness of fish (9.3 ± 2.3SE species vs. 5.3 ± 0.64SE species) and significantly longer shoreline (91.9km ± 14.9SE vs. 47.9km ± 8.8SE) as compared to the zero and medium abundance categories.

DISCUSSION

The small-population paradigm states that the size of a population is a driver of persistence (Caughley 1994), with smaller populations at greater risk for extinction (MacArthur 1972). In the case of Alberta's Western Grebes, the relationship between persistence and abundance was significantly correlated, although the recent decrease in abundance is far greater than that in persistence. This may be due to the mobile nature of migratory birds, which allows them to recolonize and continue to persist, while effects on abundance are not as easily overcome. Therefore, abundance is a key parameter to understand in this system.

Similar to the persistence model, *PropForest500m*, *PropShoreRush*, and ln*PropDevelop500m* were included in the top ordinal regression models. *PropForest500m* was negatively associated with Western Grebe abundance, again suggesting that there may be a relationship between less forested vegetation in the buffer zone and more emergent vegetation (Found et al. 2008), or that forested lakes might be marginal habitat because they tend to occur on the extreme northern edge of the Western Grebes' geographic range. These forested lakes are in direct contrast to other lakes known to support Western Grebes, such as extensive marsh systems bordered by arid desert (Lindvall and Low 1982) or prairie pothole regions within the Great Plains area (Allen et al. 2008).

As expected, bulrush (*PropShoreRush*) had a positive relationship with abundance, although it was not highly significant. However, this variable did not include other vegetation species such as common reed (*Phragmites australis*) or cattail (*Typha* spp.), in which grebes have been known to nest (Nuechterlein 1975). For instance, breeding colonies on three different lakes in Alberta (Wabamun Lake, Lake Isle, and Lac Ste Anne) all nested in different species of emergent vegetation during the 2008 season. Bulrush was included in the habitat models because it is preferred by Western Grebes (Riske 1976; Short 1984; Storer and Nuechterlein 1992) and had the greatest correlation with grebe persistence. However, other vegetation can be used for nests and cover if available, especially if bulrush is not continuous or dense enough during site selection and nest construction.

Ln*PropDevelop500m* was positively associated with Western Grebe abundance in all three top models; the lakes with the highest abundance of grebes (including breeding lakes) also had high amounts of human development in a 500m buffer surrounding the shoreline. Although this relationship was unexpected based on reports in the current literature of the negative impacts of human activity on waterbirds (Carney and Sydeman 1999), it is consistent with the results from the persistence model. Western Grebes might have become habituated to the presence of humans on these lakes, or more likely, the lake attributes best for grebes are the same as those selected by humans.

Similar selection of lakes by humans may best explain the difference in effect between high versus medium or zero abundance lakes. The higher species richness of fish coupled with the increased perimeter of shoreline on the lakes in the > 50 abundance category suggest that these lakes may simply double as attractive sites for human development as well as providing conditions supporting greater concentrations of grebes (especially breeding populations). These lakes can become ecological traps for grebes, because they currently provide a prey base and necessary nesting habitat, but also have high levels of disturbance. Increased human activity around the colony can cause nest failure or abandonment (Storer and Nuechterlein 1992). Many colonies have already experienced precipitous drops in abundance due to activities such as snowmobiling over reed beds at Isle Lake in 2002 or high levels of boating activity at Lac Ste. Anne (Yanch 2006). Increased human development is also an attractant for nest predators, such as gulls (i.e. *Larus delawarensis*) and crows (*Corvus brachyrhynchos*) (Newbrey et al. 2005; Marzluff and Neatherlin 2006)

In addition to disturbance, decreased habitat is also a major concern to grebes. Currently, habitat loss and degradation is a primary threat to birds, affecting 85% of threatened bird species worldwide (Stattersfield and Capper 2000) and almost 87% of endangered bird species in Canada (Venter et al. 2006). Because developed lakes tend to have less emergent vegetation, especially adjacent to the shoreline (Radomski and Goeman 2001), the more lakes grebes share with humans, the less likely there is to be adequate habitat. This may further exacerbate already drastic declines in Western Grebe abundance.

Decreases in lake levels also may affect the availability and quality of emergent vegetation, thus delaying or preventing Western Grebe nesting altogether (Parmelee and Parmelee 1997).

CONCLUSION

In systems where a species' persistence is tightly correlated to abundance, it can be logistically favorable to use persistence as an indicator of the viability of the population. However, abundance is an important parameter to consider with mobile species like birds, which may experience large declines while still maintaining an ability to recolonize. In the case of Alberta's Western Grebes, both persistence and abundance are related to the same habitat variables.

Although forested lakes tended to have fewer birds overall, a few sites do support large colonies and therefore should not be overlooked as conservation concerns. Stands of bulrush are frequently used by breeding Western Grebes year after year; therefore, it is not surprising that this variable was an important predictor in selected models of persistence as well as abundance. However, one must exercise caution in assuming development has a positive influence on Western Grebe persistence and abundance, especially because several studies on the effects of disturbance on waterbirds (Newbrey et al. 2005; Carney and Sydeman 1999 and references therein) and habitat loss on avian species in general (Stattersfield and Capper 2000; Gaston et al. 2003; Venter et al. 2006), suggest otherwise.

The relationship between human development and grebe abundance suggests that larger numbers of Western Grebes use lakes that are at risk for habitat degradation and may have increased disturbance in Alberta. Because the province supports such a large number of the world's breeding population, it is imperative that we reduce disturbance to the birds and their habitat as much as possible, because other negative impacts such as predation and fluctuating water levels are not as easily manipulated. Emergent vegetation (both new and old growth) should not be cleared, especially on breeding lakes. Prohibiting boating activity near birds and nesting grounds will reduce stress to nesting adults and help promote successful breeding and recruitment. Maintaining high-quality breeding habitat is an important step in mitigating the current decline in Western Grebes and can have lasting impacts on the overall global population.

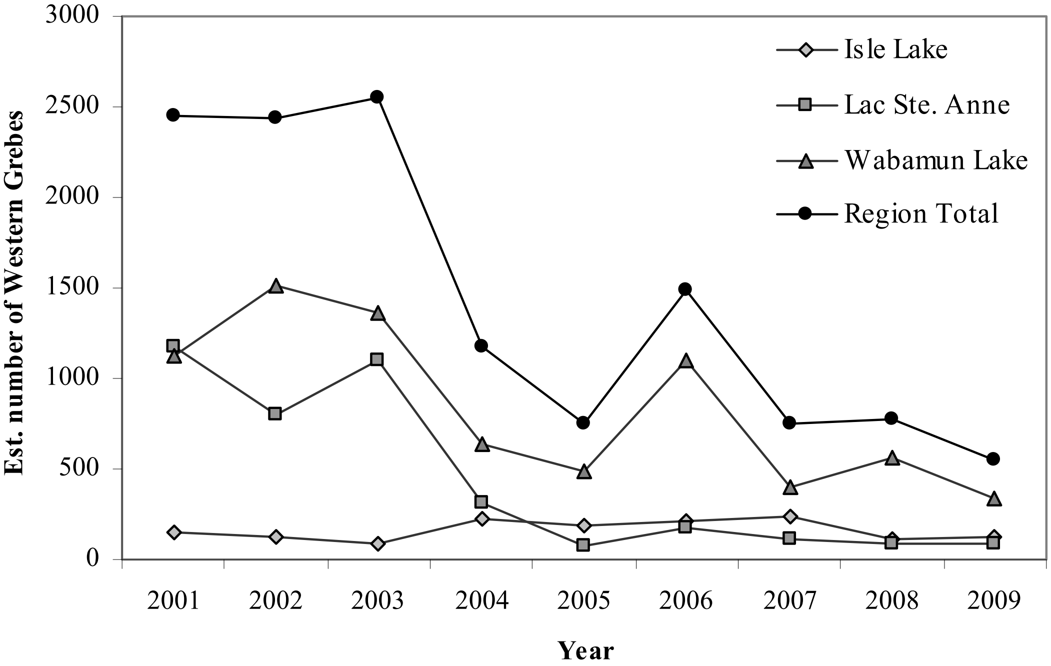

Figure 3.1: Decline in Western Grebe abundance on three lakes from the Stony Plain, AB region for which consistent abundance estimates were available. Estimates were derived from nest counts from 2001-2009. Two breeding adults were estimated per nest.

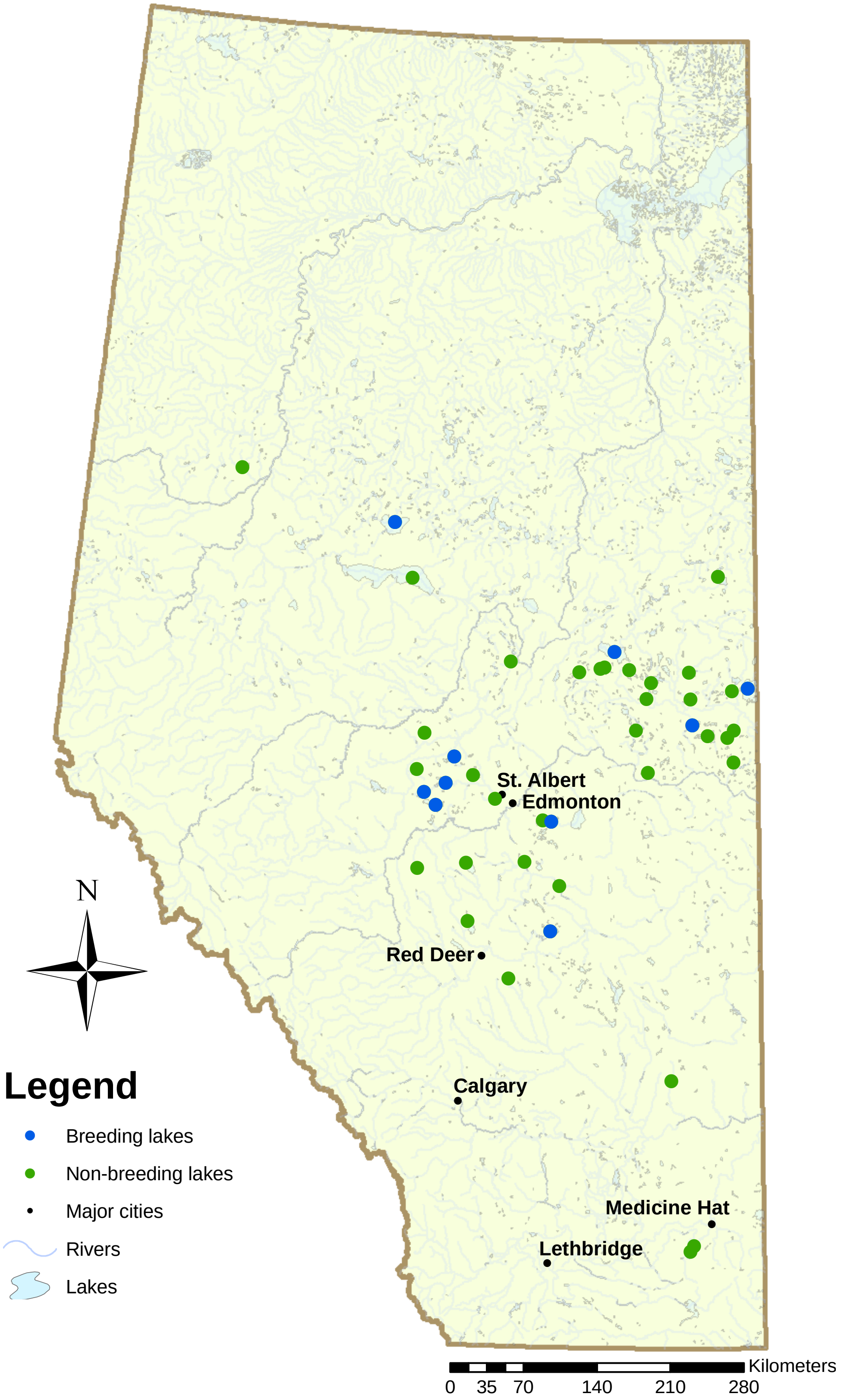

Figure 3.2: Map of study lakes (n=43) in Alberta, Canada. Breeding designation is based on observations of nests or young during summer 2008. Lake names and locations are found in Appendix A.

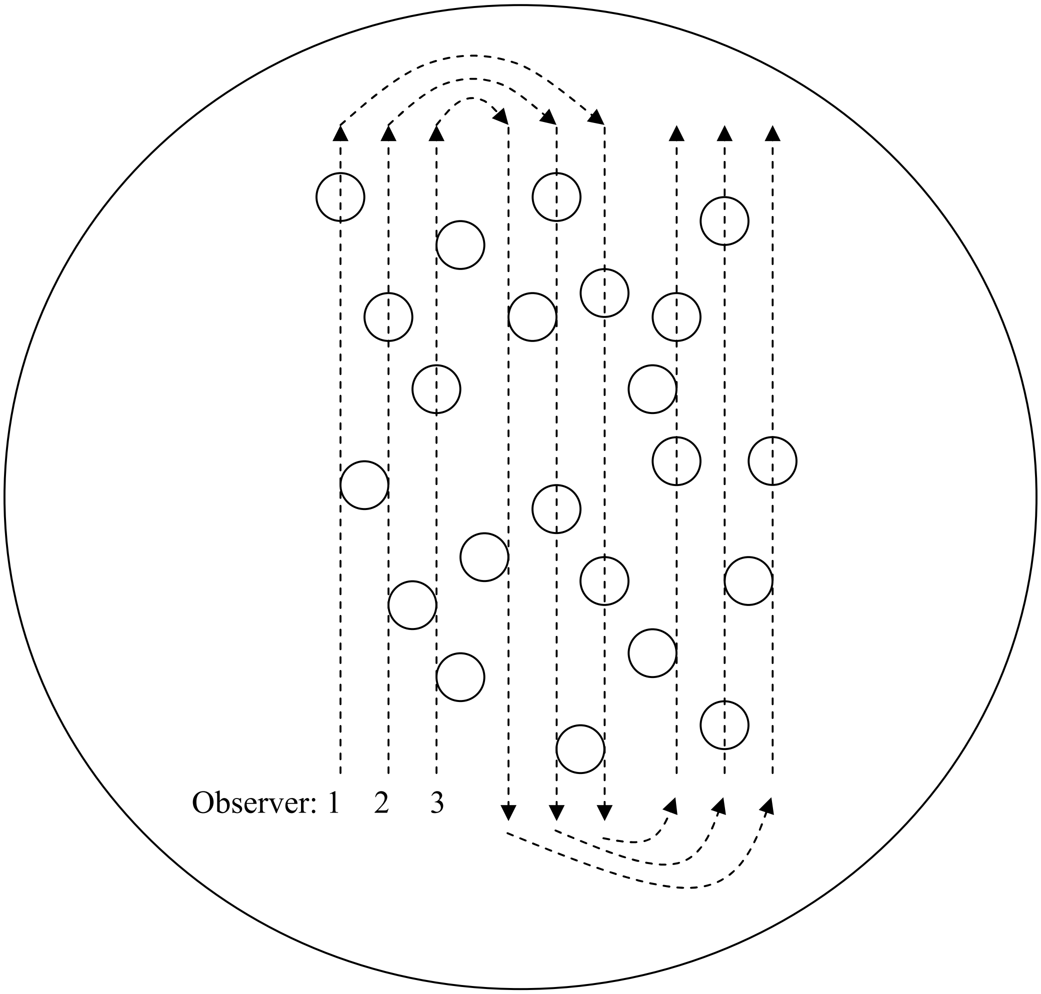

Figure 3.3: Diagram of nest count transects. Small circles represent individual nests. Dotted lines represent transects, which end a few metres beyond the edge of the colony. Observers count all nests within eye-sight along transect.

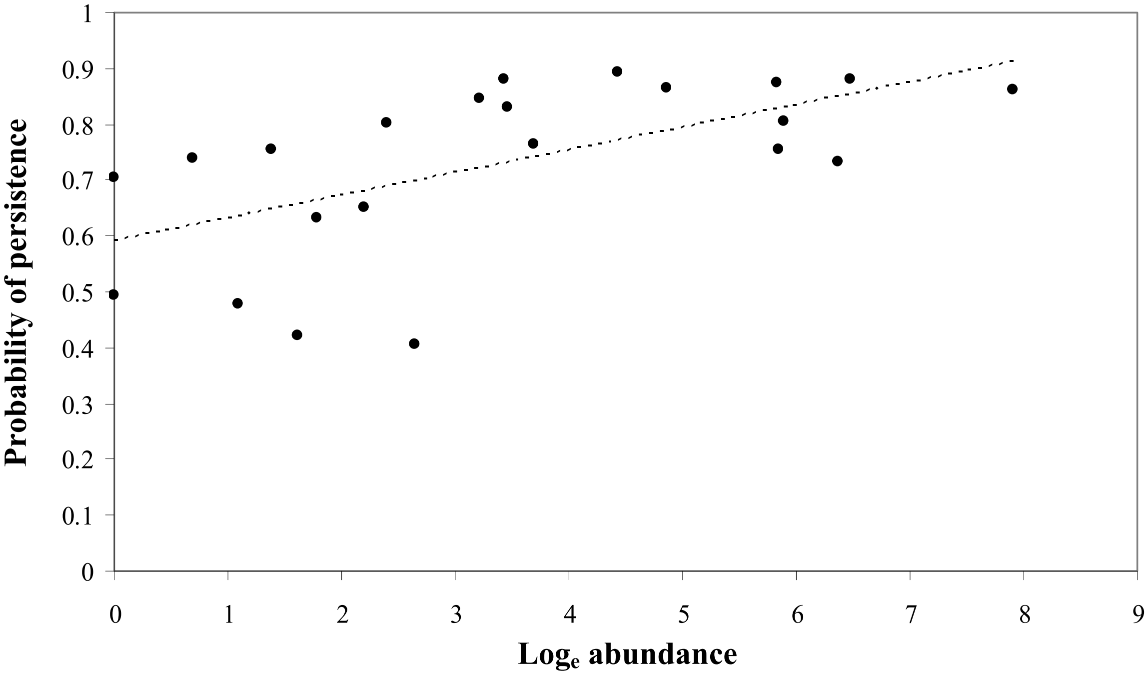

Figure 3.4: The relationship between the probability of Western Grebe persistence (from the top persistence model incorporating the amount of human development in a 500m buffer surrounding the lake) and ln Western Grebe abundance ($r = 0.59$, df = 20, $P < 0.01$). Estimates of abundance are from nest counts (2 breeding adults per nest) or brood counts (a total estimate of adults), whichever yielded the higher estimate for that year.

Table 3.1: List of site covariates collected/generated from the 2008/2009 field seasons to determine abundance relationships with Western Grebes in Alberta.

Variable Name	**Description**	**Units**	**Category**	**Source**
ln*PropDevelop500m*	Proportion of human development in 500m buffer surrounding lake ($\log_e$ transformed)	percent	Buffer_anthropogenic	1,2,3
ShoreLength	Length of lake perimeter	km	Lake	2,3
PropShoreRush	Proportion of bulrush (*Scirpus lacustris*) along shoreline	percent	vegetation	1,3
PropForest500m	Proportion of total forest in 500m buffer surrounding lake	percent	Buffer_vegetation	3
#FishSpp.	Number of different fish species in lake	Integer value	Lake	4

Sources: [1]Field [2]Aerial Photographs [3]GIS [4]Fish Management Information System (Alberta Sustainable Resource Development)

Table 3.2: Suite of *a priori* models used in ordered logistic regression. Definitions of variables are found in Table 3.1.

Model #	Model Categories/variables
	Lake
1	*ShoreLength*
2	*#FishSpp*
3	*ShoreLength* + *#FishSpp*
	Vegetation
4	*PropShoreRush*
	Buffer
5	ln*PropDevelop500m*
6	*PropForest500m*
7	ln*PropDevelop500m* + *PropForest500m*
	Lake + Vegetation
8	*ShoreLength* + *PropShoreRush*
	Lake + Buffer
9	*ShoreLength* + *lnPropDevelop500m*
	Vegetation + Buffer
10	*PropShoreRush* + ln*PropDevelop500m*
	Null
11	(no variables)

Table 3.3: AICc values (AICc) and differences from the top model (ΔAICc), model likelihoods, and model weights (w_i) for 11 *a priori* Western Grebe abundance candidate models. *K* represents the number of model parameters Models are ranked from lowest AICc score to highest.

Model	**Model variables**	***K***	**AICc**	**ΔAICc**	**Model Likelihood**	w_i
5	ln*PropDevelop500m*	3	80.95	0.00	1.00	0.42
10	*PropShoreRush* + ln*PropDevelop500m*	4	81.28	0.33	0.85	0.36
7	ln*PropDevelop500m* + *PropForest500m*	4	82.75	1.80	0.41	0.17
9	*ShoreLength* + ln*PropDevelop500m*	4	87.02	6.06	0.05	0.02
8	*ShoreLength* + *PropShoreRush*	4	87.82	6.87	0.03	0.01
2	*#FishSpp*	3	91.16	10.21	0.01	0.00
1	*ShoreLength*	3	91.55	10.60	0.00	0.00
3	*ShoreLength* + *#FishSpp*	4	92.43	11.48	0.00	0.00
4	*PropShoreRush*	3	92.93	11.98	0.00	0.00
11	(no variables)	2	93.81	12.93	0.00	0.00
6	*PropForest500m*	3	95.72	14.77	0.00	0.00

Table 3.4: Summary of the beta coefficients (β), standard errors (SE), and upper and lower 95% confidence intervals (CI) for the most parsimonious (ΔAICc<2) ordinal logistic regression models. Full definitions of the variables are found in Table 3.1.

Model	Variable	β	SE	95% CI
5	ln*PropDevelop500m*	1.02	0.30	0.42, 1.62
	Cut1	-3.98	1.09	-6.11, -1.85
	Cut2	-1.43	0.91	-3.22, 0.36
10	ln*PropDevelop500m*	1.00	0.31	0.39, 1.60
	PropShoreRush	1.90	1.33	-0.70, 4.51
	Cut1	-3.52	1.13	-5.73, -1.31
	Cut2	-0.85	0.99	-2.79, 1.09
6	ln*PropDevelop500m*	1.04	0.32	0.43, 1.66
	PropForest500m	-1.21	1.53	-4.21, 1.79
	Cut1	-4.44	1.26	-6.91, -1.96
	Cut2	-1.88	1.10	-4.04, 0.28

Table 3.5: Summary of the odds ratios (OR), standard errors (SE), and upper and lower 95% confidence intervals (CI) for the most parsimonious (ΔAICc<2) ordinal logistic regression models. Full definitions of the variables are found in Table 3.1.

Model	**Variable**	**OR**	**SE**	**95% CI**
5	ln*PropDevelop500m*	2.78	0.85	1.53, 5.06
	Cut1	-3.98	1.09	-6.11, -1.85
	Cut2	-1.43	0.91	-3.22, 0.36
10	ln*PropDevelop500m*	2.72	0.84	1.49, 4.98
	PropShoreRush	6.72	8.94	0.49, 91.29
	Cut1	-3.52	1.13	-5.73, -1.31
	Cut2	-0.85	0.99	-2.79, 1.09
6	ln*PropDevelop500m*	2.84	0.89	1.53, 5.28
	PropForest500m	0.29	0.45	0.01, 5.98
	Cut1	-4.44	1.26	-6.91, -1.96
	Cut2	-1.88	1.10	-4.04, 0.28

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CHAPTER 4

WATCH YOUR WAKE AND LET THEM DANCE! WESTERN GREBES IN ALBERTA

Alberta is home to an amazing waterbird that performs a spectacular dance across the water during springtime courtship. Western Grebes show up in Alberta shortly after ice-out in late April or early May. At this time, the birds are in full courtship and a visit to many Alberta lakes might be rewarded by a view of a male and female racing in parallel, necks arched, across the water. Or you might see another form of courtship display where two birds will push up out of the water and rub against each other while holding vegetation in their bills. Author Dave McBee remarked that “Even though both the male and the female take part, I consider their display to be one of the most bizarre and pathetic pleas for nookie by any of God's creatures.”

After forming their mating bond, the female will lay a clutch of 3-4 eggs incubated with the assistance of the male. After the eggs hatch, both male and female grebes help to take care of their chicks. Males are involved in all aspects of reproduction beginning with nest building. Beginning in late June we can see the chicks riding on their parents’ back on a number of lakes including Hastings Lake, Lac St. Anne, Wabamun Lake, Cold Lake, Lac la Biche, and Buffalo Lake. Nicknamed the “swan grebe,” the Western Grebe has a long and graceful neck, thought to be used for spearing small fish underwater. They are mostly piscivorous, meaning that they eat fish, and are expert divers.

In the fall we often see red-eyed Western Grebes swimming amongst our duck decoys, with the birds hanging on until just before freeze-up. In fact, in the thermal effluent from TransAlta's power plants at Wabamun Lake where water remains open all winter, a few Western Grebes will sometimes overwinter. But most migrate south and west to overwinter along the coast of western North America from coastal British Columbia near Vancouver to central Mexico.

Unfortunately, these spectacular waterbirds are declining in abundance throughout their range. On wintering grounds, they are vulnerable to oil-spills and gill-netting. During the breeding season, Western Grebes are sensitive to disturbance and habitat loss. Alberta Fish & Wildlife staff have been monitoring the decline in Western Grebe populations for several years, and for the past 3 yrs Mara Erickson, graduate student at the University of Alberta, has been trying to discover the cause for their decline in Alberta.

Western Grebes nest directly on the water, building precarious raft-like nests anchored to emergent vegetation, usually bulrush but sometimes in cattails or reed-grass. They nest together in colonies, with these colonies sometimes including thousands of birds. Viewing such a colony gives the impression that these birds must be abundant; in reality, this is not the case. Alberta's Western Grebes—currently listed as a Species of Special Concern under the Species at Risk Act—have experienced a nearly 40% reduction in distribution and 74% decline in abundance on 43 different lakes in Alberta where they have been observed over the past 40 years. These declines (and complete loss of breeding colonies on some lakes) coupled with a constantly changing habitat threatens the future of this species in Alberta.

Western Grebes have repeatedly been subjected to various forms of human-induced mortality. Near the end of the 19th century, thousands of birds were hunted for their coveted feathers to make hats and coats, devastating several large colonies. Populations recovered only to be reduced once more through pesticide accumulation during the mid-20th century. This caused considerable eggshell thinning and mortality of eggs and young until DDT was banned in the USA in 1972 and Canada in 1985. More recently, gill-netting and oil spills have become large-scale threats to these birds especially on their wintering range, but in Alberta as well. The 2005 CN oil spill at Wabamun Lake killed over 300 of the lake's 486 birds.

The Western Grebe has the unfortunate preference for exactly the same sorts of lakes that attract people. They prefer deeper lakes that contain fish, just like we do. Grebe lakes also tend to have relatively low amounts of forest cover surrounding the lake, and they prefer lakes with stands of bulrush along the shoreline. Grebes return to the same lake year after year, and on many lakes gradually they are facing an increasingly developed shoreline. Unfortunately, developed lakes also tend to have less emergent vegetation, because people like to clear the shoreline of undesirable "weeds." For grebes, however, this spells doom because those "weeds" are the very materials used for anchoring and building their nests—an essential element for a successful breeding season.

Grebes aren't the only critters that benefit from healthy stands of bulrush. Other colonial nesting birds such as Forster's Tern and Red-necked Grebes use emergent vegetation, and the bulrush provides important spawning and nursery habitat for many fish species. For instance, researchers have found positive relationships between the occurrence of emergent vegetation and the size of northern pike in a lake. Aquatic and emergent vegetation species even enhance the water quality itself, acting as natural filters and reducing shoreline erosion.

Recreational activity can be a serious stressor to grebes. Waves and wakes created by personal watercraft can easily swamp nests if boaters come too close to the colony. Even non-powered craft can illicit a response from grebes, as they are not fond of visitors and will dive from the nest when disturbed. Usually, the adults cover their eggs when they leave the nest, but a rushed departure can leave the eggs vulnerable to predators (especially gulls, crows, magpies, and ravens) and if left too long the eggs might chill killing the embryos inside. Boating activity has led to the loss of historical breeding colonies on Lac Ste. Anne and Thunder Lake. The only remaining colony at Lac Ste. Anne now faces disturbance from a new marina, constructed directly adjacent to the current nesting site.

To ensure future populations of Western Grebes, it is important to ensure the success of their habitats. This is a relatively easy task, requiring little more than simply leaving it be. Removal of bulrush—even the old growth from previous seasons—reduces the amount of nesting material and protection for the birds. Reducing boat speed around breeding colonies—especially during the peak nesting in June and July—eliminates wakes from boats that may flood nests or cause adults to flush from the nest. During winter, avoiding reed beds while snowmobiling will allow the old growth to remain in the spring when the birds return from their wintering grounds. (New vegetation is often too sparse by early May to establish nests, so the old bulrushes provide structure and support until the new vegetation can grow in.) This happened on Isle Lake in 2002 where snowmobilers flattened bulrush stands causing the grebes to abandon their traditional nesting area, ultimately leading to nesting failure because the birds were forced to nest in a bulrush stand that was too sparse and exposed to wind action.

After the birds have left their nesting sites to forage on the open water, it’s still important to give them ample space. They’re fun to watch, but getting too close will cause them to dive. This is a normal escape response but can be stressful to the birds, especially in late summer when they may be carrying one or more chicks on their backs.

When we go hunting or fishing the outdoor experience is much richer than the fish or game that we bring home. Having opportunity to see amazing beasts like the Western Grebe adds immeasurably to our time outdoors. So, the next time you see Western Grebes on the water, slow down and watch your wake. Keeping your distance will allow you to enjoy this unique and remarkable bird while helping it persist in Alberta.

APPENDIX A: STUDY LAKE INFORMATION

Table A.1: Names, Universal Transverse Mercator (UTM) locations, and breeding status for 43 study lakes in Alberta. Breeding lakes have the presence of nests and/or young.

Lake Name	**UTM Zone**	**Easting**	**Northing**
Angling Lake[a]	12	543835	6005890
Baptiste Lake	12	335234	6070722
Beaver Lake	12	445807	6062667
Big Lake	12	320303	5942138
Blood Indian Creek Reservoir	12	485810	5677500
Brock Lake	11	642006	5965004
Buck Lake	11	650127	5872910
Buffalo Lake[a,b]	12	372210	5817885
Cardinal Lake[a]	11	455125	623918
Coal Lake	12	347841	5882994
Cold Lake[a,b]	12	556957	6045285
Cooking Lake	12	365215	5921745
Driedmeat Lake	12	380519	5860431
Ethel Lake[a]	12	542008	6042872
Fork Lake	12	462389	6035476
Frog Lake[a]	12	543535	5975944
Garner Lake[a]	12	452413	6005834
Gull Lake	11	701351	5827118
Hastings Lake[a,b]	12	373084	5920383
Ironwood Lake	12	466550	6050373
Isle Lake[a,b]	11	650520	5944685
Kinosiu Lake	12	418973	6063742
Lac la Biche[a,b]	12	432300	6079702
Lac la Nonne[b]	11	675953	5979865
Lac Sante[a]	12	463574	5966140
Lac Ste. Anne[a,b]	11	670112	5954852
Lesser Slave Lake[a]	11	622737	6143204
Manatokan Lake	12	503511	6035198
Missawawi Lake	12	422842	6065253
Moose Lake[a,b]	12	505314	6011110
Muriel Lake[a]	12	519352	6000692
Murray Lake	12	503013	5516020
North Buck Lake[a]	12	399258	6060728
Pigeon Lake	11	695206	5881456
Pine Lake	12	332683	5773677
Reita Lake[a]	12	537912	5998883
Sandy Lake	11	694915	5963910
Seven Persons Lake	12	506849	5523042
Thunder Lake[a]	11	646501	5999938
Utikuma Lake[a,b]	11	602226	6194186
Wabamun Lake[a,b]	11	662479	5933451
Winefred Lake	12	529207	6150239
Wolf Lake[a]	12	501876	6060009

[a]Historical (prior to 2007) breeding lake [b]Current (2007-2009) breeding lake

APPENDIX B: WESTERN GREBE SURVEY DATES AND METHODS

Table B.1: Presence-absence survey dates (DD-MM) and methods during summer 2008 for 43 study lakes, where 1 = shoreline survey, 2 = scope survey, 3 = helicopter survey, 4 = nest or brood count, 5 = data obtained from ASRD, 6 = colony check.

Lake Name	**Survey 1**		**Survey 2**		**Survey 2**	
	Date	**Method**	**Date**	**Method**	**Date**	**Method**
Angling Lake	10-06	1	09-07	1	06-08	1
Baptiste Lake	17-07	1	05-08	1	25-08	1
Beaver Lake	16/17-06	1	--	--	--	--
Big Lake	24-05	1	20/21-06	1	09-08	1
Blood Indian Creek Reservoir	26-06	5	--	--	--	--
Brock Lake	27-05	2	20-07	1	25-08	1
Buck Lake	26-06	5	02-08	1	20-08	1
Buffalo Lak	26-06	5	18-07	4	13-08	1
Cardinal Lake[a]	19-06	5	--	--	--	--
Coal Lake	3/4-06	1	03-07	1	13-08	1
Cold Lake	02-07	3,5	29-07	4	22-08	6
Cooking Lake	03-06	5	25-07	1	14-08	1
Driedmeat Lake	04-06	1	03-07	1	31-07	1
Ethel Lake	11-06	1	29-07	1	21-08	1
Fork Lake	05-06	1	27-07	1	19-08	1
Frog Lake	15-07	1	--	--	--	--
Garner Lake	30-05	2	27-06	2	15-08	1
Gull Lake	26-06	5	--	--	--	--
Hastings Lake	04-06	1	21-06	1	16-07	4
Ironwood Lake	12-06	5	22-07	1	18-08	1
Isle Lake	24-06	1	23-07	4	11-08	4
Kinosiu Lake	18-06	1	21-07	1	19-08	1
Lac la Biche	21-07	6	6-08	6	19-08	6
Lac la Nonne	29-05	1	3-06	1	13-07	1
Lac Sante	09-06	1	10-07	2	15-08	1
Lac Ste. Anne	26-05	1	23-07	4	08-08	4
Lesser Slave Lake	19-06	6	14-08	5	--	--
Manatokan Lake	06-06	1	27-07	1	18-08	1
Missawawi Lake	26-06	1	30-07	1	--	--
Moose Lake	19-06	5	04-07	3	18-08	4
Muriel Lake	8/9-07	1	06-08	1	17-08	1
Murray Lake	12/13-06	1	--	--	--	--
North Buck Lake	17-07	1	05-08	1	25-08	1
Pigeon Lake	13-06	5	--	--	--	--
Pine Lake	03-07	1	01-08	1	20-08	1
Reita Lake	10-06	1	--	--	--	--
Sandy Lake	26-05	1	25-06	1	04-08	1
Seven Persons Lake	12-06	1	--	--	--	--
Thunder Lake	28-05	1	19-06	5	12-07	1
Utikuma Lake	12-08	5	19-08	5	27-08	5
Wabamun Lake	XX-05	5	23-06	1	25-07	4
Winefred Lake	02-07	3,5	--	--	--	--
Wolf Lake	28/29-06	1	26-07	1	22-08	1

APPENDIX C: WESTERN GREBE ABUNDANCE ESTIMATES

Table C.1: Latest (2007-2009) abundance estimates and maximum historical abundances for 43 study lakes in Alberta. Blank cells indicate that no maximum abundance estimates were available. All historical data was obtained from Alberta Sustainable Resource Development Species at Risk (SAR) or Wildlife Status Reports (WSR), except data from the 2007 and 2008 field season.

Lake Name	Latest abundance estimate*	Maximum abundance estimate	Max. abundance year	Source of max. abundance estimate
Angling Lake	1	1,680	1981	SAR #88
Baptiste Lake	0	--	--	--
Beaver Lake	0	--	--	--
Big Lake	0	3	1982	WSR #60
Blood Indian Creek Reservoir	3	3	2008	2008 field data
Brock Lake	0	6	2006	SAR #121
Buck Lake	32	32	2008	2008 field data
Buffalo Lake	362[a]	1,030	2006	SAR #121
Cardinal Lake	0	30	2000	SAR #7
Coal Lake	0	6	2004	SAR #94
Cold Lake	582[a]	1,982	2003	SAR #88
Cooking Lake	4	7	2004	SAR #94
Driedmeat Lake	5	5	2008	2008 field data
Ethel Lake	0	84	1981	WSR #60
Fork Lake	11	11	2008	2008 field data
Frog Lake	0	600	1991	WSR #60
Garner Lake	0	102	1985	WSR #60
Gull Lake	25	320	2004	SAR #94
Hastings Lake	346[a]	440	2006	SAR #121
Ironwood Lake	0	--	--	--
Isle Lake	130	234	2007	2007 field data
Kinosiu Lake	0	--	--	--
Lac la Biche	2,716[a]	4,612	2003	SAR #88
Lac la Nonne	31	40	1992	WSR #60
Lac Sante	0	50	1987	WSR #60
Lac Ste. Anne	84[a]	1,268	2001	SAR #41
Lesser Slave Lake	2	3,742	2002	WSR #60
Manatokan Lake	9	9	2008	2008 field data
Missawawi Lake	1	1	2008	2008 field data
Moose Lake	649[b]	649	2008	2008 field data
Muriel Lake	40	600	1991	WSR #60
Murray Lake	14	14	2008	2008 field data
North Buck Lake	2	124	1991	WSR #60
Pigeon Lake	1	100	1971	WSR #60
Pine Lake	2	6	1976	WSR #60
Reita Lake	0	532	1981	WSR #60
Sandy Lake	0	150	2002	WSR #60

(cont).

Table C.1: ***(cont.)***

Lake	**Latest abundance estimate***	**Maximum abundance estimate**	**Year of max. abundance estimate**	**Source of max. abundance estimate**
Seven Persons Lake	2	2	2008	2008 field data
Thunder Lake	4	251	1980	WSR #60
Utikuma Lake	6	1,680	2000	SAR #7
Wabamun Lake	340[a]	1,510	2002	WSR #60
Winefred Lake	0	--	--	--
Wolf Lake	0	720	1985	WSR #60
TOTAL ESTIMATE	**5,404**	**22,635**	--	--

*Latest estimates from 2008 except: Isle (2009), Lac la Biche (2007), Lac Ste Anne (2009), Wabamun (2009).

[a] Estimate from nest count [b] Estimate from brood count