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Research Paper

Habitat associations with counts of declining Western Grebes in Alberta, Canada

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ABSTRACT. During the past several decades, numbers of Western Grebes (*Aechmophorus occidentalis*) have declined throughout their breeding and wintering ranges in North America. We estimated Western Grebe abundance and documented habitat factors between 2007 and 2009 from 43 lakes in Alberta, Canada where Western Grebes historically have occurred, to (1) compare Western Grebe abundance with the relative probability of persistence, and (2) identify habitat correlates of grebe abundance. The relative probability of Western Grebe persistence was correlated with abundance in the study area, although only 19% of the variation in persistence probability was explained by abundance. Western Grebe abundance was positively correlated with the shoreline extent of emergent bulrush (*Scirpus lacustris*), which is consistent with past studies and underlies the importance of protecting emergent vegetation in efforts to conserve Western Grebes. Grebe abundance also was positively correlated with a longer shoreline perimeter, but was inversely correlated with the amount of forested backshore, which occurred on lakes primarily at the northern margins of Western Grebe range. The amount of backshore development was positively associated with Western Grebe abundance, which might reflect a preference for similar lake characteristics by humans and grebes. These relationships are important to consider in the context of implementing and managing recovery of the Western Grebe in Alberta.

Associations entre l'habitat et les dénombrements de Grèbe élégant, une espèce en diminution en Alberta, Canada

RÉSUMÉ. Durant les quelques dernières décennies, le nombre de Grèbes élégants (*Aechmophorus occidentalis*) a diminué dans l'ensemble de son aire de nidification et d'hivernage en Amérique du Nord. Nous avons estimé l'abondance du Grèbe élégant et documenté les paramètres d'habitat entre 2007 et 2009 sur 43 lacs en Alberta, Canada, où ce grèbe était présent dans le passé, dans le but de : 1) comparer son abondance avec la probabilité relative de persistance, et 2) déterminer les caractéristiques d'habitat liées à son abondance. La probabilité relative de persistance du Grèbe élégant était corrélée avec son abondance dans l'aire d'étude, quoique 19 % seulement de la variabilité de la probabilité de persistance était expliquée par l'abondance. L'abondance de ce grèbe était positivement corrélée avec l'étendue de joncs émergents (*Scirpus lacustris*) sur les rives, un résultat conforme aux études passées et qui souligne l'importance de protéger la végétation émergente pour la conservation du Grèbe élégant. L'abondance de ce grèbe était aussi corrélée positivement avec un grand périmètre de rive, mais était inversement corrélée avec la quantité de haut de plage forestier, qu'on trouve principalement sur les lacs situés à la limite nord de l'aire du Grèbe élégant. Le degré de sinuosité du haut de plage était positivement associé avec l'abondance de ce grèbe, ce qui reflète sans doute une préférence pour des caractéristiques de lacs similaires chez les humains et les grèbes. Ces relations sont importantes à considérer dans la mise en place et la gestion du rétablissement du Grèbe élégant en Alberta.

Key Words: *abundance; Aechmophorus occidentalis; Alberta; avian conservation; ordinal regression; population size; threatened species; Western Grebe*

INTRODUCTION

The Western Grebe (*Aechmophorus occidentalis*), a Species of Special Concern in Canada, has decreased in both distribution and abundance throughout its North American range (COSEWIC 2014). Declines in abundance have been noted in British Columbia, where the species is on the Red List as imperiled (Burger 1997, British Columbia Conservation Data Centre 2015), and in California (Robison et al. 2015), including areas that once had some of the largest concentrations of wintering Western Grebes (Burger 1997, Puget Sound Action Team 2007). The decline in wintering regions is thought to be partially a result of a southerly geographic shift of the species' distribution due to prey availability (Wilson et al. 2013). In Alberta, the Western Grebe was recently listed as Threatened, following similar patterns of decline and due to its sensitivity to disturbance and habitat loss (AESRD and ACA 2013). Not only has Western Grebe occupancy decreased by 37% on 43 lakes in Alberta that historically supported grebes (Erickson et al. 2014), but declines in abundance have been much more pronounced—up to an estimated 63% loss of breeding adults over the past 15 years in some regions (Fig. 1). Based on the latest provincial population estimate of 9549 birds in 2012, Alberta supports 10–14% of the world's breeding population of Western Grebes (AESRD and ACA 2013, COSEWIC 2014). Considering these data, the Alberta Western Grebe population should be an important focus for conservation.

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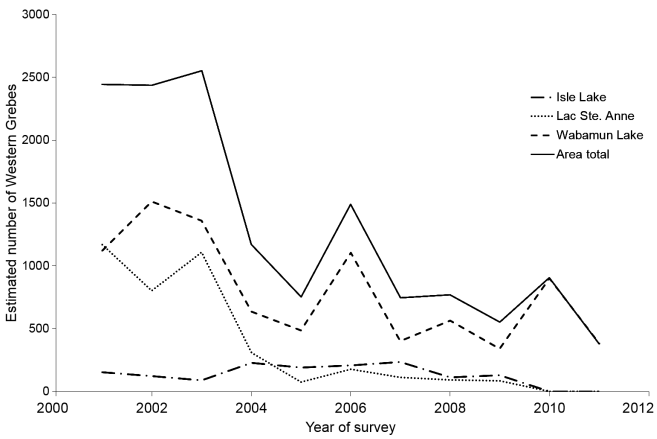
Fig. 1. Decline in Western Grebe abundance on three lakes in the Stony Plain, Alberta region. Estimates were derived from the greater total of (1) nest counts (two breeding adults estimated per nest) or (2) complete lake surveys from 2001 to 2011 (modified from AESRD and ACA 2013).



Past studies have reported factors correlated with occupancy of the Western Grebe, including fish-bearing lakes and ice-free periods for nesting (Nuechterlein 1975, Riske 1976, Forbes 1984, Found et al. 2008), as well as correlates of persistence (constancy in occupancy over time) (Rahel 1990) probability. The relative probability of persistence of the Western Grebe was modeled relative to key habitat variables on Alberta lakes throughout its breeding range that were known to have supported the species (Erickson et al. 2014); Western Grebe persistence on a subset of once-occupied lakes was positively correlated with the proportion of shoreline bulrush (*Scirpus lacustris*), and was inversely related to the proportion of forested backshore. As well, Western Grebes have persisted on many lakes with extensive human development.

As a general pattern, in ecology, occupancy is correlated with abundance (Andrewartha and Birch 1954), having been documented in a diversity of taxa (Winters and Wheeler 1985, Gibbons et al. 1993, Mossman et al. 1998, Gaston et al. 1997). Indeed, for a variety of applications, occupancy surveys have been used to predict abundance (Nachman 1981, He and Gaston 2003, Royle and Nichols 2003, Boyce et al. 2016). However, in the context of a threatened species like the Western Grebe, it is important to examine occupancy and abundance separately because a high probability of persistence might be the result of a historically large Western Grebe colony rather than a reflection of current abundance. As well, systematic count surveys provide context for the creation of species recovery plans for threatened and/or endangered species because count data are used both to establish a baseline and as a target population estimate at which the species could be considered sufficiently recovered. Publicly accessible citizen-science databases such as eBird (Sullivan et al. 2009) provide an opportunity to submit opportunistic sightings but may not provide information on the number of birds or breeding status at a site. Finally, because habitat loss remains one of the top threats to the world's endangered avian species (Wilcove et al. 1998, Stattersfield and Capper 2000, Wells 2007), exploring how habitats relate to abundance can facilitate better management and conservation of habitats on lakes that continue to support Western Grebes.

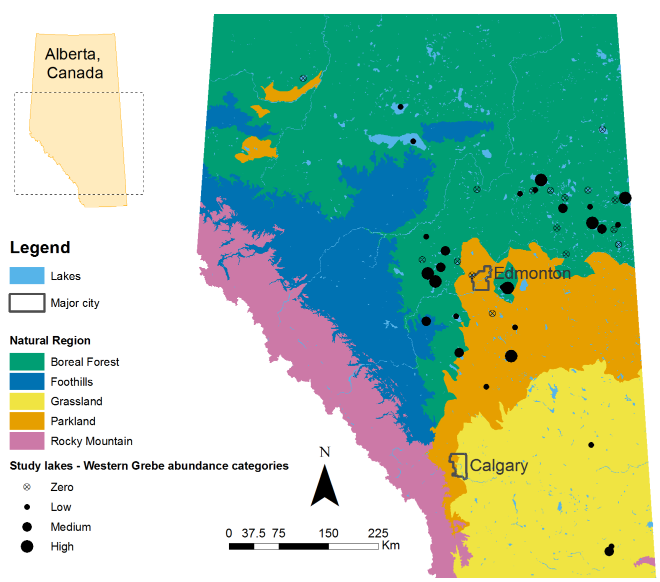
We examine the strength of the relationship between Western Grebe abundance (i.e., surveyed number of adults on a lake) and the relative probability of persistence on a suite of lakes that either historically supported or currently support grebes, and the relation between categories of Western Grebe abundance and habitat covariates. If persistence probability and abundance are not highly correlated, factors related to persistence might be different from those associated with abundance, thereby suggesting different implications for Western Grebe habitat conservation.

METHODS

Study area

Data on Western Grebe abundance were collected on 43 lakes at which the species was known to occur within the past 40 years in Alberta's Boreal Forest, Parkland, and Grassland regions (Fig. 2). In addition, each of the lakes was characterized for covariates that we hypothesized to be important environmental characteristics for the grebes. By focusing on lakes with a history of Western Grebe presence, we hoped to ascertain site suitability for continued support of the species.

Fig. 2. Distribution of study lakes (n = 43) in Alberta, Canada. Study lake symbology reflects sites with zero (0 birds), low (1–10 birds), medium (11–100 birds), or high (> 100 birds) Western Grebe abundance. See Appendix 1 for lake names, regions, and breeding designations.



The Boreal Forest region covers the northernmost part of the province and is bordered by the Foothills region to the west and Parkland region to the south. Major vegetation includes trembling aspen (*Populus tremuloides*) and balsam poplar (*P. balsamifera*), white spruce (*Picea glauca*), black spruce (*P.

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 Parkland region includes the most populated areas in the province, including the cities of Edmonton, Red Deer, and Calgary. Wetlands make up between 8% and 10% of this region (Natural Regions Committee 2006). Vegetation in the region represents the transition between the northern boreal forest and southern grasslands, often with stands of aspen interspersed with grasslands. The Grassland region of southern Alberta consists of mostly agricultural lands and native grassland (e.g., *Festuca* spp.). Lakes comprise less than 2% of this region (Natural Regions Committee 2006).

Abundance surveys

During May through August 2008–2009, we conducted surveys for Western Grebe abundance, and characterized habitat variables on lakes in Alberta's Boreal Forest (n = 34), Parkland (n = 6), and Grassland (n = 3) regions (Fig. 2). All surveys were conducted between 0700 and 1600 hours.

Our 43 study lakes were a subset of lakes surveyed by Alberta Environment and Parks (AEP), at which the Western Grebe historically had occurred since at least 1970, and included all known major breeding colonies since 1970. Historically, surveys for Western Grebes in Alberta were largely opportunistic, but they have become more consistent since 2000, with data reported in provincial species-at-risk reports. To remain consistent with data presented in these reports, we used AEP survey techniques to collect data on Western Grebe abundance, including nest counts, brood counts, and shoreline waterbird surveys. Survey method was dependent on the size of lake and whether there was a known Western Grebe breeding colony present. Nest counts provided an estimate of Western Grebe abundance on a particular lake, while brood counts and shoreline waterbird surveys yielded a count of Western Grebe adults. Each lake was surveyed three times within the study period; the highest estimate or count of Western Grebes was used in analysis (see Appendix 1 for abundance data and survey method).

Nest counts

On lakes with breeding colonies of Western Grebes, nest counts frequently are used as a proxy for adult Western Grebe abundance, with two breeding adults estimated per nest counted (Resources Inventory Committee 1999, Hanus et al. 2002). To minimize disturbance, we conducted nest counts in late July and early August, shortly after chicks hatched and left the nesting site. Observers entered the colony in chest waders or kayaks/canoes (depending on the water level). Nests were counted on straight-line transects along the length of the colony, with two to five observers within eyesight of each other. Distance between observers varied depending on the observed density of nests and density of vegetation; more nests and/or denser vegetation required narrower transects. Transect length extended a few metres beyond the edge of the colony to ensure that all nests were counted. For one lake on which a nest count was not conducted in 2008 or 2009 due to logistic factors and to minimize disturbance, the 2007 estimate was used in the analysis (see Appendix 1). All colonies were visited in either 2008 or 2009, however, to confirm breeding activity.

Brood counts

We conducted brood counts on a subset of breeding lakes during mid-August 2008 and 2009 to (1) confirm nest count estimates, and (2) document recruitment (Resources Inventory Committee 1999). One boat driver and one to two observers surveyed the lake using a systematic boat survey (Hanus et al. 2002), and stopped at predetermined points along transects in the open water to count all adult and juvenile birds that were visible from that location. We used brood count data for adult abundance in the data analysis if nest count data were not available for a particular breeding lake, or if the brood count data yielded a higher adult abundance estimate for that year (Appendix 1).

Shoreline waterbird surveys

Shoreline waterbird surveys were used to collect Western Grebe abundance data on nonbreeding lakes, following techniques outlined by the Resources Inventory Committee (1998). Surveys were conducted from a kayak (for lakes < 5 km^2), or motor-powered watercraft for medium (5–50 km^2) or large (> 50 km^2) lakes. From within the kayak or boat, we scanned the lake using binoculars while keeping a distance from the shoreline of 20–200 m, depending on visibility and water depth. The entire lake was surveyed to obtain a complete count of all Western Grebes (see Appendix 1 for abundance survey results).

Habitat surveys

Shoreline habitat surveys were conducted from the water (in either a kayak or boat), 20–400 m from shoreline, with distance from the shore dependent on visibility. We recorded the extent (m) along the shoreline of emergent macrophyte species known to provide nesting habitat, including cattail (*Typha* spp.), common reed grass (*Phragmites australis*), and bulrush (Wollis and Stratmoen 2010, LaPorte et al. 2013). Surveys were conducted as early as possible during the study period to record data for habitat variables shortly after spring migration and Western Grebe lake selection (throughout May/early June).

Within a geographical information system (GIS) ArcMap (Environmental Systems Research Institute 2008), we used both georeferenced aerial photography and satellite imagery (0.5–1.0 m resolution) to digitize and calculate additional variables, including shoreline perimeter and linear extent of emergent vegetation, as well as proportion of human development and proportion/type of backshore vegetation within a 500-m buffer surrounding each lake (see Found et al. 2008, Erickson et al. 2014). Anthropogenic development and emergent vegetation were digitized using ground-truthed data and digital aerial photography as a reference. We used a GIS land cover raster layer (Agriculture and Agri-Food Canada 2008) to calculate the amount and type of terrestrial vegetation and human land use in the 500-m buffer.

Western Grebes are mainly piscivorous (LaPorte et al. 2013). Fish density was a preferred metric to use in our models; however, the data available were limited to species richness. Therefore, we used the number of fish species per lake (from Alberta Environment and Parks' Fish and Wildlife Management Information System [FWMIS]) as a metric for prey occurrence. Maximum lake depth levels were also obtained from FWMIS.

Table 1. Site covariates used in Western Grebe abundance ordinal regression models.

Variable name	Description	Units
Development Proportion[†‡§]	Proportion of human development in 500-m buffer surrounding lake ($\log_e$ transformed)	Percent
Shoreline Length[‡§]	Length of lake perimeter	Kilometres
Bulrush Proportion[†§]	Proportion of bulrush (*Scirpus lacustris*) along shoreline	Percent
Forest Proportion[§]	Proportion of total forest in 500-m buffer surrounding lake	Percent
Fish Species[ǀ]	Number of different fish species in lake	Integer value
Lake Depth[ǀ]	Maximum lake depth	Metres

Sources: [†]Field; [‡]Aerial photographs; [§]GIS; [ǀ]Fish Management Information System (Alberta Environment and Parks)

Covariates were log-transformed if needed to obtain a normal distribution (Hosmer and Lemeshow 2000, Vittinghoff et al. 2005), and were examined for multicollinearity. In the case of high correlation ($|r| > 0.65$) between covariates, we retained the covariate with the highest predictive ability from a univariate analysis (Hosmer and Lemeshow 2000). Covariates retained in the ordinal regression analysis are listed in Table 1.

Persistence–abundance association

We related Western Grebe abundance at the 27 occupied lakes to the relative probability of persistence at each lake. The relative probability of persistence was estimated using the top-ranked model from Erickson et al. (2014), which was based on Western Grebe occupancy data collected on the same suite of lakes and over the same time period as this study. The persistence model is the log-linear function:

$$P(x) \sim \exp(\beta_1 x_1 + \beta_2 x_2 + \cdots \beta_n x_n) \qquad (1)$$

where $P(x)$ is proportional to the probability of persistence, $\beta_1 \ldots \beta_n$ are coefficients estimated from the data, and x is a vector of predictor covariates, $x_1, x_2, \ldots x_n$ (Erickson et al. 2014). We used a correlation coefficient to determine the strength of the relationship between the two parameters. Analyses were conducted in Stata 12.0 (StataCorp 2011).

Abundance models

We used ordered logistic regression to relate Western Grebe abundance to habitat covariates. Modeling actual abundance is a preferred method of analysis, but small sample size and skewed number of both unoccupied lakes (i.e., zeros) and lakes with high Western Grebe abundance necessitated an alternative approach. Ordinal regression models can be used to compare ranked categories of a response variable when the differences between categories are not necessarily equal (Guisan and Harrell 2000, Long and Freese 2006).

Western Grebe abundance was divided into four categories to compare unoccupied (0 Western Grebe adults), low (1–10 adults), medium (11–100 adults), and high (> 100 adults) abundance lakes, with categories selected to ensure reasonable dispersion of observations into groups for multinomial analysis. We modeled abundance categories as a function of six habitat variables (Table 1) within 12 a priori models, including a null model (Table 2). A proportional odds ratio was used to compare the highest abundance category with the lower categories for each predictor variable (UCLA 2009). We tested for the proportional odds assumption to determine if there was a difference in the coefficients between models, while a likelihood ratio test was used to compare each model to a null model without count predictors to test the significance of the model overall (UCLA 2009). Alternative models were compared using AICc for small sample size, an information-theoretic approach (Burnham and Anderson 2002).

Table 2. Alternative a priori Western Grebe abundance candidate models and their AICc values (AICc), differences from the top model (ΔAICc), model likelihoods, and model weights (wi). K represents the number of model parameters. Models are ranked from lowest AICc score to highest.

Model	K	AICc	ΔAICc	Model likelihood	w_i
Development	4	106.470	0.00	1.00	0.32
Development + Bulrush	5	106.544	0.07	0.96	0.31
Shoreline + Development	5	107.097	0.63	0.73	0.23
Development + Forest	5	108.286	1.82	0.40	0.13
Shoreline + Bulrush	5	114.825	8.36	0.02	0.00
Fish	4	117.026	10.56	0.01	0.00
Bulrush	4	118.624	12.15	0.00	0.00
Shoreline	4	118.986	12.52	0.00	0.00
Shoreline + Fish	5	119.148	12.68	0.00	0.00
Null	3	120.182	13.71	0.00	0.00
Lake depth	4	121.693	15.22	0.00	0.00
Forest	4	122.166	15.70	0.00	0.00

RESULTS

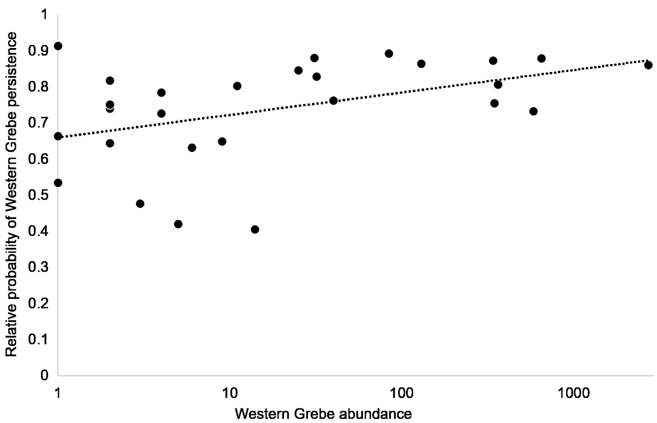
Abundance data

Western Grebes were observed at 27 of the 43 study lakes during 2008–2009 (Appendix 1), with lakes classified as zero (n = 16), low (n = 13), medium (n = 7), or high (n = 7) abundance lakes. Ten lakes had evidence of breeding (presence of nests or young) during the study period, as compared to 21 historical breeding lakes, and all but two breeding lakes (Utikuma Lake and Lac la Nonne) had an established breeding colony with abundance ranging from 84 to 2716 birds (mean = 651, SE = 303). Adult grebe abundance on all occupied lakes ranged from 1 bird to 2716 birds, with a mean of 200 (SE = 103.02) and a median of 11 birds. All lakes within the "high" abundance category had established breeding colonies at the time of surveying. Although in some cases the recorded abundance differed slightly between repeated surveys on a lake within the season, no differences resulted in a change of a lake's abundance category in the ordinal regression analysis.

Persistence–abundance association

The relationship between Western Grebe abundance and relative probability of persistence was significant ($r = 0.44$, df = 25, $P < 0.05$) (Fig. 3). However, abundance data accounted for only 19% of the variance in persistence.

Fig. 3. The relationship between Western Grebe abundance and the relative probability of Western Grebe persistence (as calculated from the top persistence model in Erickson et al. [2014]). The relative probability of grebe persistence is correlated with ln(grebe abundance) for 27 occupied lakes ($r = 0.44$, $R^2 = 0.19$, df = 25, $P < 0.05$).



Abundance models

The top ordinal logistic regression models (ΔAICc < 2) had habitat covariate combinations of *Development Proportion, Bulrush Proportion*, *Shoreline Length,* and *Forest Proportion* (Table 2), and were a substantial improvement ($P < 0.05$) over the null model according to the likelihood ratio test. *Development Proportion* was significantly associated with Western Grebe abundance, as was *Shoreline Length*, although only marginally. *Bulrush Proportion* and *Forest Proportion* exhibited positive and negative associations with grebe abundance, respectively, although these associations were not significant (Table 3).

According to the odds ratio (OR), lakes with a higher proportion of shoreline covered by bulrush were roughly 6.87 times more likely to have more than 100 grebes than were the medium, low, or zero abundance categories (Table 3). Lakes with increased development in a surrounding 500-m buffer (OR = 2.91) also favored higher ranked abundance categories, while an increased amount of forest in a 500-m buffer favored lower abundance categories or no birds at all (OR = 0.29) A greater shoreline perimeter (OR = 1.01) showed little to no association with higher abundance categories (Table 3).

DISCUSSION

The small-population paradigm states that the size of a population is a driver of persistence (Caughley 1994, Boyce 2002), with smaller populations at greater risk for extinction (MacArthur 1972). Indeed, in Alberta, the relative probability of Western Grebe persistence and abundance were significantly correlated, although the recent decrease in abundance is far greater than that in persistence, and abundance accounted for only 19% of the variance in the relative probability of persistence. This could 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. To that end, although we surveyed only lakes with a history of Western Grebe occurrence, we were confident that we monitored the regional population because the provincial Department of Environment and Parks was monitoring other lakes in the area for waterbirds. As well, the species' tendency toward site fidelity in Alberta—especially on lakes with established breeding colonies—coupled with provincially gathered waterbird data on additional lakes, suggests that the decline of Western Grebe on some lakes is not countered by a notable increase of the species elsewhere in the region.

Forest Proportion, *Bulrush Proportion*, and *Development Proportion* emerged as important parameters in our Western Grebe abundance models, with *Bulrush Proportion* and *Development Proportion* having positive coefficients and *Forest Proportion* displaying an inverse relation with higher abundance categories. These results are similar to those in the top persistence probability models from Erickson et al. (2014). However, we found that *Shoreline Length* was associated with abundance, whereas it had not been related to the relative probability of persistence in Erickson et al. (2014). Although we believe that the relationship between abundance and the parameters in the top models hold biological significance, we note that statistical significance remains weak given our limited sample size.

Forest Proportion was inversely associated with Western Grebe abundance, perhaps because the surveyed lakes with a high proportion of forested backshore occur primarily on the extreme northern edge of the species' geographic range. As a result, the habitat surrounding these forested lakes is vastly different from other lakes known to support the Western Grebe, such as those within extensive marsh systems bordered by arid desert (Lindvall and Low 1982) or prairie pothole regions in the Great Plains (Allen et al. 2008). Nevertheless, substantial Western Grebe breeding colonies still occur on some of the more northerly lakes in our study area. Of these, a colony on Lac la Biche is within a designated Important Bird Area (Bird Studies Canada 2015), and the Cold Lake colony location is generally inaccessible to disturbance by motor watercraft due to the presence of a sandbar that separates the colony from the main lake body. Although these colonies have not been immune to the decline in abundance seen in other areas of the province, they so far have remained viable.

As expected, the proportion of shoreline bulrush was positively related to Western Grebe abundance. However, this variable did not include other vegetative species in which grebes have been known to nest, such as common reed grass or cattail (Nuechterlein 1975). For instance, breeding colonies on three lakes in Alberta (Wabamun Lake, Lake Isle, 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, LaPorte et al. 2013) and had the greatest correlation with the relative probability of grebe persistence (Erickson et al. 2014). 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 periods.

Although the length of shoreline was not a major predictor of grebe persistence probability (Erickson et al. 2014), it had a slight positive association with Western Grebe abundance, which suggests that a greater amount of shoreline may support larger numbers of birds. If the shoreline length is relatively large due to a complex geometry of sheltered bays or areas protected from wind and wave action, that lake might serve as an attractive site for breeding colony establishment.

Fish species richness did not contribute appreciably to any of the top models. However, we acknowledge that although the general pattern between occupancy and abundance (He and Gaston 2003) indicates that fish species richness might have some value as a crude index, obtaining estimates of abundance for species of fish that grebes use as prey could be a fruitful area for future research on patterns of grebe abundance.

Development Proportion was positively associated with Western Grebe abundance; i.e., lakes with the highest number of grebes also had high amounts of human development in a 500-m buffer surrounding the shoreline. Although this relationship was unexpected given negative impacts of human activity on waterbirds (Carney and Sydeman 1999) and the sensitivity of the Western Grebe to disturbance (AESRD and ACA 2013), it is consistent with the Erickson et al.'s (2014) persistence probability model, as well as results from Somers et al. (2015), who found that Western Grebe density was relatively high on two lakes in Saskatchewan, Canada, even in areas with increased shoreline development and recreational use. These findings suggest that the Western Grebe might have become habituated to the presence of humans on such lakes, or that the lake attributes preferred by grebes (i.e., large, deep, fish-bearing waterbodies) are the same as those selected by humans. In the latter case, these shared sites might be ecological sinks for Western Grebes, as suggested by Somers et al. (2015).

Loss of breeding season habitat is a major concern for Western Grebes in Alberta. Indeed, habitat loss and degradation is a primary threat to birds generally, 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), loss of adequate habitat is a threat to Western Grebes at both breeding and nonbreeding sites. In Alberta, many known breeding colony sites already have experienced changes in habitat suitability due to activities such as snowmobiling over reed beds at Isle Lake in 2002 or high levels of boating activity at Lac Ste. Anne (AESRD and ACA 2013). Therefore, recreational lake use and development should be mitigated in a way that it does not destroy shoreline and/or emergent vegetation, especially at known breeding colony sites.

CONCLUSION

In systems where a species' persistence and abundance are strongly correlated, it may be logistically favorable to use probability of persistence as an indicator of the viability of the population. However, abundance is an important parameter to consider with mobile species like birds that could experience large population declines while still maintaining an ability to recolonize a site. In addition—as in the case with the Western Grebe in Alberta—abundance data can be used to establish both baseline and target recovery populations of a threatened or endangered species.

Although forested lakes tended to have fewer grebes overall, a few northerly sites still support large colonies, and therefore should not be overlooked as conservation concerns. Applying protective notations or designating Important Bird Areas such as the case on Lac La Biche can be a first step to protecting specific colony locations. Specific bulrush stands within a lake frequently are used by breeding grebes year after year; therefore, it is not surprising that this variable was an important predictor in selected models of abundance. Lakes with a greater shoreline perimeter appear to have a greater effect on abundance (particularly large numbers of grebes) than on relative probability of persistence for Western Grebes. The relation between development and high abundance of Western Grebes shows that co-existence continues to be possible for this species. However, one must exercise caution in assuming this is a casual relationship, in light of several studies on the effects of disturbance on waterbirds (Carney and Sydeman 1999, Newbrey et al. 2005) and anthropogenically driven habitat loss on avian species in general (Stattersfield and Capper 2000, Gaston et al. 2003, Venter et al. 2006). Furthermore, although current abundance is high, annual surveys show that these colonies continue to decline overall (i.e., Fig. 1). Additional insight is needed into the effects of recreational lake use and/or development on patterns of Western Grebe abundance to better ascertain the success of this species over time on highly developed or recreational lakes. In the meantime, the species' persistence and (relatively) high abundance on developed lakes is promising.

Because Alberta supports such a large proportion (10–14%) of the world's Western Grebe breeding population, it is imperative that we mitigate threats to the birds and their habitats. Lakes with a greater shoreline perimeter might be important targets for conserving what remains of Alberta's large colonies. Emergent vegetation (both new and old growth) should not be removed, especially on breeding lakes. Moving forward, gaining insight into the effects of habitat covariates, including anthropogenic activity, on abundance will be an important step in mitigating the current decline of Western Grebe while promoting recovery in the province.

Responses to this article can be read online at:
http://www.ace-eco.org/issues/responses.php/980

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Appendix 1

Study lake locations and Western Grebe abundance at 43 lakes in Alberta. Abundance data obtained from shoreline surveys unless otherwise noted. All data from 2008 except: Isle (2009), Lac la Biche (2007-see footnote), Lac Ste Anne (2009), Wabamun (2009).

Lake Name	Natural Region	Lake location (UTM)	Abundance estimate
Angling Lake	Boreal	12U 543835m E 6005890m N	1
Baptiste Lake	Boreal	12U 335234m E 6070722m N	0
Beaver Lake	Boreal	12U 445807m E 6062667m N	0
Big Lake	Parkland	12U 320303m E 5942138m N	0
Blood Indian Creek Reservoir	Grassland	12U 485460m E 5677647m N	3
Brock Lake	Boreal	11U 642006m E 5965004m N	0
Buck Lake	Boreal	11U 650127m E 5872911m N	32
Buffalo Lake[†]	Parkland	12U 372210m E 5817885m N	362[‡]
Cardinal Lake	Boreal	11V 455125m E 6232918m N	0
Coal Lake	Parkland	12U 347841m E 5882994m N	0
Cold Lake[†]	Boreal	12U 556957m E 6045285m N	582[‡]
Cooking Lake	Boreal	12U 365215m E 5921745m N	4
Driedmeat Lake	Parkland	12U 380519m E 5860431m N	5
Ethel Lake	Boreal	12U 542008m E 6042872m N	0
Fork Lake	Boreal	12U 462389m E 6035476m N	11
Frog Lake	Boreal	12U 543535m E 5975944m N	0
Garner Lake	Boreal	12U 452413m E 6005834m N	0
Gull Lake	Parkland	11U 701352m E 5827119m N	25
Hastings Lake[†]	Boreal	12U 373084m E 5920383m N	346[‡]
Ironwood Lake	Boreal	12U 466550m E 6050373m N	0
Isle Lake[†]	Boreal	11U 650519m E 5944684m N	130
Kinosiu Lake	Boreal	12U 418973m E 6063742m N	0
Lac la Biche[†]	Boreal	12U 432300m E 6079702m N	2,716[‡,‖]
Lac la Nonne[†]	Boreal	11U 675953m E 5979865m N	31
Lac Sante	Boreal	12U 463574m E 5966140m N	0
Lac Ste. Anne[†]	Boreal	11U 670112m E 5954852m N	84[‡]
Lesser Slave Lake	Boreal	11U 622737m E 6143204m N	2
Manatokan Lake	Boreal	12U 503511m E 6035198m N	9
Missawawi Lake	Boreal	12U 422842m E 6065253m N	1
Moose Lake[†]	Boreal	12U 505314m E 6011110m N	649[§]
Muriel Lake	Boreal	12U 519352m E 6000692m N	40
Murray Lake	Grassland	12U 503611m E 5516404m N	14
North Buck Lake	Boreal	12U 399258m E 6060728m N	2
Pigeon Lake	Boreal	11U 695206m E 5881456m N	1

Pine Lake	Parkland	12U 332683m E 5773677m N	2
Reita Lake	Boreal	12U 537912m E 5998883m N	0
Sandy Lake	Boreal	11U 694915m E 5963910m N	0
Seven Persons Lake	Grassland	12U 507333m E 5523738m N	2
Thunder Lake	Boreal	11U 646501m E 5999938m N	4
Utikuma Lake†	Boreal	11U 602226m E 6194186m N	6
Wabamun Lake†	Boreal	11U 662479m E 5933451m N	340‡
Winefred Lake	Boreal	12U 529207m E 6150239m N	0
Wolf Lake	Boreal	12U 501876m E 6060009m N	0

†Evidence of breeding during the 2008-2009 season. All breeding lakes except Utikuma Lake and Lac la Nonne had an established colony at the time of surveying.

‡Estimate from nest count

§Estimate from brood count

|Estimate from 2007 used in analysis as 2008 surveys yielded only a partial nest count. This does not affect the ordinal regression category for Lac la Biche.