University of Alberta

Ring-necked pheasant (*Phasianus colchicus*) habitat selection in southeastern Alberta

by

©

Tammy Lynn McLash

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

Master of Science

in

Environmental Biology and Ecology

Department of Biological Sciences

Edmonton, Alberta
Spring 2008

Your file Votre référence
ISBN: 978-0-494-45856-3
Our file Notre référence
ISBN: 978-0-494-45856-3

ABSTRACT

I identified landscape characteristics that govern the distribution and abundance of ring-necked pheasants (*Phasianus colchicus*) in southeastern Alberta based on spring cock crow-counts conducted in the Eastern Irrigation District. I also examined species richness and bird community composition associated with pheasant occurrence. Pheasant occurrence was positively associated with forage habitat, linear density of watercourses, and density of vegetation patches indicating that vegetation cover and interspersion of essential habitats are important to pheasants. Surprisingly, pheasant abundance was positively associated with distance from pheasant release sites. This indicates that releasing pheasants might make release sites unfavorable areas for wild pheasants due to excessive hunting pressure or displacement of wild birds by released birds. Pheasant occurrence was associated with increased avian species richness; however, the assemblage of birds associated with pheasants was typical of disturbed agricultural lands. Management plans need to consider factors that influence both occurrence and abundance to effectively manage pheasants.

This thesis is dedicated to the love of my life without whom this dream would never have been pursued.

ACKNOWLEDGEMENTS

Firstly, I would like to thank my husband, Mathew, for always supporting and encouraging me. Your love helped me through all the ups and downs of this graduate experience. I also thank my family for always believing in me.

I thank my supervisor, Mark Boyce, for his support and guidance throughout this process. I thank my committee members, Susan Hannon and Edward Bork, for their helpful suggestions for my project.

My research would not have possible without financial support from Pheasants Forever Calgary, Alberta Conservation Association Grant Eligible Conservation Fund, and Alberta Sport, Recreation, Parks & Wildlife Foundation. In particular, I am grateful for David Bissett's generosity and support of wildlife research.

Many people in the Eastern Irrigation District office helped me immensely with my project in the field, gathering GIS data, or just talking pheasants, including: Rick Martin, Margo Jarvis Redelback, Greg Feth, Mark Porter. I would especially like to thank Rick Martin for sharing his wisdom about pheasants with me and for his encouragement and continued support of my project.

I am thankful that many people were interested in my project and took time to discuss my project and general pheasant issues with me, including: Bob Haysom, Reg Russell, Ed Houck, Randy Lee, and Brad Taylor.

I was blessed to have been surrounded by a fantastic group of lab mates, including: Carrie Roever, Cathy Shier, Jen Carpenter, Shevenell Mullen, Kyle Knopff, Chris Desjardins, Christine Robichaud, Gabriela Yates, Justin Pitt, and Ewen Clark. I would like to sincerely thank Scott Nielsen for his invaluable statistical advice. A special thanks also goes out to Charlene Nielsen who guided me through the wonderful world of GIS with patience and thoughtful advice.

I thank Sandra Hajash for welcoming me into her home and for making me feel like one of the family. I truly appreciated your hospitality.

Last, but definitely not least, I would like to thank my field assistant Robin for her hard work and cheery smile (even at 3am).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

GENERAL INTRODUCTION

The ring-necked pheasant (*Phasianus colchicus*) is a popular game species that is native to Asia. It was introduced to North America in 1881 with the release of birds in Oregon (McAtee 1945, Lever 1987). The first successful introduction of ring-necked pheasants into Alberta occurred in 1908 (Alberta Fish and Wildlife Division 1973, Royal Alberta Museum 2006, SRD 2007). Pheasant populations established most of their current range throughout North America by the late 1930's (Burger 1988). Pheasants have adapted to North American ecosystems and they have become one of the most popular and well-known introduced birds in North America.

Pheasants belong to the order Galliformes. They are large game birds (males are 76-91cm in length and females are 53-64cm in length) (Udvardy 1977) with long tapered tails. The males have a brilliant green head, a bright red eye patch, and a ring of white feathers around their necks. Unlike the males, females do not have brightly coloured feathers but instead are an overall mottled-brown colour. Pheasants' diet consists of a variety of foods including waste grain, weed seeds, fruits, leaves, and insects (McAtee 1945, Hill and Robertson 1988).

Pheasants have a polygamous mating system. Every spring, males establish and actively defend territories by crowing in attempts to attract a harem of females to mate with. Males take no part in the incubation or raising of chicks. Females construct nests on the ground and lay between 6-14 eggs (Udvardy 1977). Similar to the young of other gallinaceous species, pheasants have precocial young that are able to run around and eat soon after hatching.

Pheasants in Alberta are at the northern edge of their North American range (Kimball et al. 1956) and have been declining since the late 1970's (Dahlgren 1988, Sauer et al. 2005). One factor that may contribute to their decline is a decrease in the amount of seasonal habitats (Robertson et al. 1993) related to changes in agricultural land-use practices. Farms are increasing in size resulting in less edge in the form of fencerows and windbreaks, and larger areas of monoculture (Warner 1994, Statistics Canada 2006). More intensive agricultural practices such as "clean farming" have been adopted to increase crop production. "Clean farming" practices reduce both food and cover resources by cultivating road allowances, removing inconvenient patches of brush, and draining wetlands (Brown 1941, Warner 1999). Increasing use of chemical control of weeds and insects also is reducing food and cover available for use by pheasants (Rodgers 2002). These changes in the agricultural landscape have altered habitat conditions for pheasants, as well as other grassland wildlife.

Previous studies have used small-scale site conditions to evaluate pheasant habitats. However, recently biologists have realized the importance of information concerning landscape configuration (Schmitz and Clark 1999, Clark et al. 1999). Assessing habitats across landscapes is facilitated by satellite imagery (remote sensing), geographic information systems (GIS), and habitat modelling. With these recent technological advances, we are better able to quantify the relationship between pheasant distribution and landscape features, and formulate more effective management plans for pheasants.

The main focus of my research was to examine pheasant habitat use in the Eastern Irrigation District. In Chapter 2, I model the occurrence of pheasants using resource selection functions (Manly et al. 2002), identifying vegetation and anthropogenic features important to describing pheasant habitat use. I also identify the composition of bird communities associated with pheasants. In Chapter 3, I expand upon my occurrence models and investigated factors influencing the abundance of pheasants across the landscape using zero-inflated negative binomial models (Nielsen et al. 2005, Long and Freese 2006). General conclusions and management recommendations are included in Chapter 4. I am planning to submit my research findings to the *Journal of Wildlife Management*.

1. LITERATURE CITED

Alberta Fish and Wildlife Division. 1973. Alberta pheasants – habitat and hen seasons. Wildlife Management Series No. 3.

Alberta Sustainable Resource Development [SRD]. 2007. Living with fish and wildlife, game species, pheasant. <http://www.srd.gov.ab.ca/fishwildlife/livingwith/huntingalberta/pheasant.aspx>. Accessed 5 November 2007.

Brown, L. 1941. The management of farm wildlife. Transactions of the Kansas Academy of Science 44:381–388.

Burger, G. V. 1988. 100 years of ringnecks: an historical perspective on pheasants in North America. Pages 1–26 *in* D. L. Hallett, W. R. Edwards, and G. V. Burger, editors. Pheasants: symptoms of wildlife problems on agricultural lands. North Central Section of The Wildlife Society, Bloomington, Indiana, USA.

Clark, W. R., R. A. Schmitz, and T. R. Bogenschutz. 1999. Site selection and nest success of ring-necked pheasants as a function of location in Iowa landscapes. Journal of Wildlife Management 63:976–989.

Dahlgren, R. B. 1988. Distribution and abundance of the ring-necked pheasant in North America. Pages 29–43 *in* D.L. Hallett, W.R. Edwards, and G.V. Burger, editors. Pheasants: symptoms of wildlife problems on agricultural lands. North Central Section of The Wildlife Society, Bloomington, Indiana, USA.

Hill, D., and P. Robertson. 1988. The pheasant: ecology, management and conservation. BSP Professional Books, London, England.

Kimball, J. W., E. L. Kozicky, and B. A. Nelson. 1956. Pheasants of the plains and prairies. Pages 204–263 *in* D. L. Allen, editor. 1956. Pheasants in North America. The Stackpole Co., Harrisburg, P.A. and Wildlife Management Institute, Washington, D.C., USA.

Lever, C. 1987. Naturalized birds of the world. John Wiley and Sons, Inc., New York, New York, USA.

Long, J. S., and F. Freese. 2006. Regression models for categorical dependent variables using Stata. Stata Press, College Station, Texas, USA.

Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Kluwer, Dordrecht, The Netherlands.

McAtee, W. L. 1945. The ring-necked pheasant and its management in North America.

The American Wildlife Institute, Washington, D. C., USA.

Nielsen, S. E., C. J. Johnson, D. C. Heard, and M. S. Boyce. 2005. Can models of presence-absence be used to scale abundance? Two case studies considering extremes in life history. Ecography 28:197–208.

Robertson, P. A., M. I. A. Woodburn, W. Neutel, and C. E. Bealey. 1993. Effects of land use on breeding pheasant density. Journal of Applied Ecology 30:465–477.

Rodgers, R. D. 2002. Effects of wheat-stubble height and weed control on winter pheasant abundance. Wildlife Society Bulletin 30:1099–1112.

Royal Alberta Museum. 2006. Creature collection: ring-necked pheasant. <http://www.royalalbertamuseum.ca/vcollects/detail.asp?Grp=Birds&Genus=Phasianus&Species=colchicus>. Accessed 5 November 2007.

Sauer, J. R., J. E. Hines, and J. Fallon. 2005. The North American Breeding Bird Survey, Results and Analysis 1966–2004. Version 2005.2. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Schmitz, R. A., and W. R. Clark. 1999. Survival of ring-necked pheasant hens during spring in relation to landscape features. Journal of Wildlife Management 63:147–154.

Statistics Canada. 2006. 2006 Census of Agriculture, Farm Data and Farm Operator Data. Statistics Canada Catalogue no. 95-629-XWE.

Udvardy, M. D. F. 1977. The Audubon Society of field guide to North American birds-western region. Alfred A. Knopf, Inc., New York, New York, USA.

Warner, R. E. 1994. Agricultural land use and grassland habitat in Illinois: future shock for Midwestern birds? Conservation Biology 8:147–156.

Warner, R. E., P. C. Mankin, L. M. David, and S. L. Etter. 1999. Declining survival of ring-necked pheasant chicks in Illinois during the late 1900s. Journal of Wildlife Management 63:705–710.

CHAPTER 2

UNDERSTANDING RING-NECKED PHEASANT (*Phasianus colchicus*) DISTRIBUTION IN THE EASTERN IRRIGATION DISTRICT

1. INTRODUCTION

Habitat selection by animals often is related to their basic requirements for food, shelter, and reproductive activities. Ring-necked pheasants (*Phasianus colchicus*) are most commonly found in farmlands, pastures, grassy woodland edges, and wetland areas. In spring, male pheasants establish territories on open ground near the edge of dense cover to display for females (Taber 1949, Lachlan and Bray 1976). Females establish breeding ranges near male territories (Taber 1949, Burger 1966, Dumke and Pils 1979, Hill and Ridley 1987). Male pheasants use areas with taller vegetation, such as forage lands, for shelter and concealment from predators (Lachlan and Bray 1976). Wetland areas with dense cattails provide thermal cover and protection, especially during winter (Robertson et al. 1993, Gabbert et al. 1999), and are often the foci of their annual home range (Homan et al. 2000). Irrigation ditches provide dense cover for pheasants near cropland and water sources. Open crop fields are important for feeding and display areas during spring (Wagner 1965). Standing cover, such as harvested grain fields with 50-cm stubble, provide overhead cover and a source of food for ring-necked pheasant broods (Meyers et al. 1988). Pheasants are an "edge" species (Leopold 1933) thriving in areas where there is a mixture of cultivated farmland, available water source, and escape cover.

"Edge" species are primarily associated with the perimeter of a habitat patch (Bender et al. 1998) and generally require simultaneous availability of more than one type of habitat (Yahner 1988). High interspersion of essential habitats for species with low radius of mobility, such as ring-necked pheasants, is necessary to maintain populations (Leopold 1933). Changes to agricultural land-use practices, such as eliminating unwanted plant cover and planting larger areas of monoculture, may reduce the proximity of important habitat patches for pheasants. Therefore, the interspersion of seasonal habitats is an important component of landscape structure that can shape habitat quality for pheasants.

Habitat quality also may be influenced by the amount of human activity occurring in the area. The economy within the Eastern Irrigation District's boundaries is driven mainly by agriculture and oil and gas (Statistics Canada 2002). This results in the study area having over 800 farm homesteads (Statistics Canada 2006) and over 30, 000 oil and gas wells. Anthropogenic disturbances often have a negative impact on bird species in the area (Warner et al. 2000, Endrulat 2005). Knowledge of how anthropogenic features shape the quality of habitat for pheasants is another important component to evaluate.

The agricultural landscape has changed in recent years with the advancement of technology. Changes in agricultural land-use practices resulting in the reduction of habitats are hypothesised to be one factor contributing to pheasant population declines (Robertson et al. 1993). To offset the impact a reduced wild pheasant population may have on hunting opportunities, pheasants are raised and released within the Eastern Irrigation District. Male pheasants are released at seven locations during the fall hunting season to supplement the wild population. Without being augmented by captive-bred releases, the southeastern Alberta pheasant population would likely disappear. Therefore in my study, distance to nearest release site might influence pheasant occurrence.

Pheasants, especially males, are conspicuous, both physically and behaviorally. In today's dynamic agricultural landscape, pheasants play an important role in making people aware about the wildlife around them. People often see male pheasants display for the females in open areas. Also, pheasants are popular game birds that many people enjoying hunting. Pheasants may act as a focal species that can be used to encourage landowners to enhance habitats for pheasants and other wildlife. Riley and Schulz (2001) have even suggested that ring-necked pheasant populations play a significant role in today's dynamic agricultural landscape by acting as an "ecological barometer" of the health (biodiversity) of our agricultural landscapes. By improving habitats for pheasants, we are in turn improving habitats for many wildlife species that live in the agricultural landscapes of Alberta.

On the other hand, pheasants are an introduced species and some conservation groups argue that management priority should be for native species. My research results provide information about the influence of landscape characteristics on pheasant distribution within the Eastern Irrigation District, as well as the bird communities associated with pheasants. Knowledge of the extent and distribution of potentially suitable landscapes for pheasants can help land managers make informed decisions and enhance habitat management in Alberta.

The focus of the study was to understand landscape variables that determined the distribution of pheasants in the Eastern Irrigation District. I focused on male habitat selection because it has been postulated that the availability of suitable breeding territories limits local abundance of breeding males, which in turn, could limit densities of breeding females (Robertson 1996). As well, females generally select breeding ranges near males' territories (Taber 1949, Burger 1966, Dumke and Pils 1979, Ridley and Hill 1987), therefore by enhancing habitats for male pheasants, female pheasants also benefit. The specific objectives were to: (1) identify landscape attributes associated with pheasant spring habitat use, (2) use an RSF model to develop a habitat-use map identifying key pheasant habitats in the Eastern Irrigation District, (3) determine the relationship between bird species richness (biodiversity) and pheasant occurrence, and (4) identify the bird communities that might benefit from enhancement of pheasant habitats. Ultimately, this information can be used to develop plans for effective pheasant habitat management in Alberta.

2. STUDY AREA

This study was conducted in the Eastern Irrigation District (EID) of southeastern Alberta (Figure 2.1), near the northern limit of the ring-necked pheasants' North American range. The EID was centred on Brooks, Alberta between the Bow River to the north and the Red Deer River to the south. The study area contained approximately 6,000 km^2 characterised by large irrigation reservoirs, cultivated farmland, dry mixed-grass native prairie, and some wetlands. Irrigated agriculture within the EID consisted of 34% cropland (combination of 23% cereals and 11% specialty crops and oil seeds) and 66% forage land. Grassland in the EID consisted of native mixed-grass prairie. Forage land in the EID mainly consisted of alfalfa and tame hay/fodder crops. Cropland in the EID mainly consisted of wheat, oats, barley, and canola. Major economic drivers in the area included farming, oil, gas, ranching, and recreation. Brooks was also home to the Provincial pheasant hatchery (renamed Canadian Pheasant Company in 1999) that has been operating since 1945. The Canadian Pheasant Company releases male pheasants during the fall hunting season at seven release sites within the EID.

3. METHODS

3.1 Crow-count Surveys

Crow-count surveys were conducted during April and May 2006. This timeframe was selected to encompass the peak of seasonal crowing activity of pheasant cocks (Kimball 1949, Burger 1966). Surveys were conducted 40 minutes prior to sunrise until 50 minutes after sunrise because crowing intensity was relatively constant during this period (Kimball 1949). Roadside surveys were conducted under satisfactory weather conditions (no precipitation and winds ≤20km/hr) (Robbins 1981, Sauer et al. 2005).

The EID has conducted surveys since 1965 to monitor the pheasant population. Currently the EID monitors 16 routes once annually, typically in the third week of April. Crow-count survey routes were selected through stratification of the study area so that three main habitat types (native grassland, cropland, and forage land) within the study area were sampled (Manly 1992). Proportional allocation with respect to the area of each habitat type within the EID was used to determine the number of routes per habitat type. Native grassland occupied the greatest amount of area within the EID, followed by forage land and cropland, respectively. Using Hawth's Tools in ArcGIS 9.1 (ESRI 2005), I generated random points within each habitat type. The secondary road closest to the random point location was used as the starting point. Using this method, 54 routes were randomly located on secondary roads that did not overlap with the existing EID survey routes. A total of 70 routes were monitored with number of stops per route ranging from 5 to 20 (Figure 2.2).

Stop points were located at 1.6-km (1 mile) intervals along each route. Surveys began one minute after arriving at the stop point to allow the birds to resume their normal activity after any potential disruption due to our vehicles. The sampling period was three minutes during which the presence or absence of male pheasants heard or seen crowing was recorded and distance to each crowing male was estimated. All routes were surveyed three times: at the beginning (April 1 – 20), middle (April 21 – May 10), and end of field season (May 11 – 31). Route order, stop point order, and observer were changed with each survey event to minimize biases.

Differences in bird detectability can occur as a result of anthropogenic disturbances, different environmental conditions, or bird behaviour (McKenzie et al. 2006). Standardised methods and observer expertise were used to minimize detection biases. Also routes were surveyed three times to increase the chances of hearing a pheasant if one was indeed present. Detection probability is the probability that at least one individual of a species is detected during sampling of an occupied site (McKenzie et al. 2006). Using the program PRESENCE to model detection probability (McKenzie et al. 2006), the naïve detection probability estimate was 78%. Due to limited sampling occasions per site and the assumption by program PRESENCE of independence of sampling points, I was unable to incorporate detection probability into my models. However, due to the high naïve detection probability estimate of 78%, conspicuous behaviour of pheasants, use of consistent methods, and the open prairie habitats in which the routes were located, I do not believe that detection was a major source of bias in the surveys.

In addition to recording the presence or absence of pheasants, I also recorded the presence of other bird species heard or seen at each stop point. These data provided insight into species richness in the EID and species that might benefit from habitat enhancements for pheasants.

3.2 Predictor Variables

Many vegetation, anthropogenic, and other landscape features influence pheasant habitat selection. Only biologically relevant variables were considered for model building as per Hosmer and Lemeshow's procedure (Hosmer and Lemeshow 2000). I identified a set of variables in a GIS that I hypothesised would predict the occurrence of pheasants on the landscape. Additional landscape configuration metrics were calculated using FRAGSTATS software (McGarigal et al. 2002). The maximum distance pheasants were heard crowing was 600m, therefore I used 600m for the radius of the circular moving window used to generate my GIS variables. I used Hawth's Tools "Intersect Point Tool" in ArcGIS 9.1 (ESRI 2005) to extract variable values within the 600m-radius circle surrounding each stop point.

The predictor variables fell into two main categories: vegetation features and anthropogenic features (Table 2.1). First, I used Agricultural Canada's Prairie Farm Rehabilitation Administration landcover digital data (PFRA) to determine the amount of grassland, forage land, and cropland within each buffered stop point. These vegetation variables have been found to be important to pheasants in previous studies (Lachlan and

Bray 1976, Clark et al. 1999). I ground truthed the PFRA layer at each stop point and determined it to accurately portray vegetation features within the EID. I also conducted paired *t*-tests to compare my vegetation assessment and the PFRA assessment at each stop point. There were no significant differences between my vegetation assessment and the PFRA assessment of the amount of cropland ($t = 1.66$, $P = 0.098$, difference = 3%), grassland ($t = -0.71$, $P = 0.48$, difference = -2%), and forage land ($t = 0.57$, $P = 0.57$, difference = 1%) at each stop point. Second, I used Alberta Base Features to calculate the mean linear density ($m \cdot m^{-2}$) of watercourses within a 600m-radius circular moving window around each stop point. The watercourses layer includes canals, rivers, lakes, and reservoirs. Habitats surrounding water have been found to be important for shelter for pheasants (Robertson et al. 1993) and are often the foci of their annual home range (Homan et al. 2000). Third, I identified "patches" of grassland, forage land, cropland, and watercourses within each buffered stop point using the PFRA and Alberta Base Features layers. I then used the FRAGSTATS software (McGarigal et al. 2002) to calculate a variety of edge metrics based on these vegetation "patches" because pheasants have been described to be an edge species (Leopold 1933). Variables calculated using the FRAGSTATS software were edge density, patch density, contiguity index, contagion, and total edge (McGarigal et al. 2002).

Anthropogenic features also were included in my analysis. Human activity can negatively impact wildlife species (Warner et al. 2000, Endrulat 2005). Distance to nearest pheasant release site was calculated for every stop point. The density of homes was calculated by counting the number of homes within the 600m-radius circular moving window around each stop point. Also, the linear density ($m \cdot m^{-2}$) of pipelines was calculated using Alberta Base Features.

3.3 Pheasant Occurrence Model

Based on a literature review, models were constructed using only variables that were biologically relevant to pheasant habitat selection. Prior to building statistical models, I used univariate mixed-effects logistic regressions to assess the importance of individual variables in distinguishing used from unused stop points (Hosmer and Lemeshow 2000). To reduce the number of variables included in the model building process, only variables with relatively important β coefficients ($P < 0.25$ threshold; Hosmer and Lemeshow 2000) were retained. I assessed collinearity between all predictor variables using Pearson's correlations with a cutoff limit of $|r| \geq 0.6$. If two variables were correlated, I kept the variable with the lowest *P*-value obtained during the univariate analysis. I also examined all predictor variables for outliers and nonlinearities by visually inspecting the data (Hosmer and Lemeshow 2000). Using the multiple working hypotheses approach (Chamberlain 1965, Anderson et al. 2000), I developed 13 *a priori* candidate models using the remaining predictor variables (Table 2.2).

I evaluated pheasant habitat selection at the population level using resource selection functions (RSFs) based on a design I method with used and unused resource units (Manly et al. 2002). Resource selection functions are defined to be any function that is proportional to the probability of use of a resource unit (Manly et al. 2002) and are a useful tool to examine habitat selection. Used/unused data may yield a resource selection probability function (RSPF), which is the actual probability of use of a resource unit (Manly et al. 2002), however, it is difficult to identify unused resource units with absolute certainty (Johnson et al. 2006). Therefore, because of my inability to explicitly account for detection variation in my modelling, I decided to consider these models as RSFs. Stop points with pheasants present (1) were compared to stop points without pheasants (0) using mixed-effects logistic regression. A random effect was used to account for the lack of independence between my stop points along each route (Gillies et al. 2006). I generated RSFs for all candidate models. All analyses were conducted using STATA 9.1 (STATA 2005).

I chose to apply the information-theoretic approach to model selection by using Akaike's Information Criteria (AIC) (Burnham and Anderson 2002). AIC was calculated using the formula:

$$AIC = -2(\text{log-likelihood}) + 2K$$

where the log-likelihood is from the mixed-effects logistic regression model and K is the number of parameters in the model. Models are ranked according to their AIC value (smallest to largest). AIC differences (Δ_i) are calculated by comparing each candidate model to the best model (model with lowest AIC value). Models with $\Delta_i < 2$ have substantial support while models with Δ_i between 3 and 7 have less support (Burnham and Anderson 2002). Akaike weights (w_i) were used to assess the weight of evidence that a particular model was the best model given the set of candidate models (Burnham and Anderson 2002). The predictive capacity of the models was tested using Receiver Operating Characteristic (ROC) curves (Boyce et al. 2002). The ROC curve plots the sensitivity (probability of detecting a true signal) versus 1 − specificity (the probability of detecting a false signal). The area under the curve (AUC) can have values ranging between 0.5 and 1. AUC provides a measure of the model's ability to discriminate. ROC values between 0.7 and 0.8 are considered acceptable discrimination, ROC between 0.8 and 0.9 are considered to have excellent discrimination, and ROC greater than 0.9 are considered to have outstanding discrimination (Hosmer and Lemeshow 2000). The top-ranked model was extrapolated to the entire study area using Spatial Analyst (ESRI 2005) to create a habitat-use map for pheasants.

3.4 Bird Association Model

In addition to pheasant habitat-selection modelling, I also examined species richness (biodiversity) and bird community composition associated with pheasant occurrence. My dependent variable was pheasant occurrence (presence (1) or absence (0)). My independent variables were the presence (1) or absence (0) of different bird species.

First, I used species richness (the total number of species heard at each stop point) as a measure of biodiversity to address the issue of using pheasants as an "ecological barometer" of landscape health (biodiversity). I assessed the relationship between pheasant occurrence and species richness using mixed-effects logistic regression. I used a random effect to account for the lack of independence of route stop points (Gillies et al. 2006). I used a Wald χ^2 statistic to assess the fit of the model.

Second, I used principal components analysis (PCA) to summarize the relationships in the bird community data (Green 1979, Hirst and Jackson 2007). PCA is a multivariate statistical technique used to reduce the number of variables in the data by creating a few key components to explain variation in the data (Gotelli and Ellison 2004).

I examined the screeplot of eigenvalues versus PCA components to determine the number of principal components that most effectively characterized the data (Gotelli and Ellison 2004). Once the number of components was determined, I examined the component loadings to understand the underlying structure of each component. I then used mixed-effects logistic regression to evaluate the relationship between pheasant occurrence and the principal components of the bird community data. I used a random effect to describe the non-independence within groups of stop points (Gillies et al. 2006). Model fit and component coefficient significance were determined using the Wald χ^2 statistic. Statistical tests were performed in STATA 9.1 (STATA 2005).

4. RESULTS

In April and May 2006, I surveyed 70 routes with a total of 498 stop points. Pheasants were present at 64% of the stop points (N=498) (Figure 2.3).

4.1 Pheasant Occurrence Model

Twelve biologically relevant variables were considered for inclusion in pheasant occurrence candidate models. Because all FRAGSTATS variables were correlated, I selected the FRAGSTATS variable (patch density) with the lowest *P*-value obtained during the univariate analysis to represent the edge and interspersion components of habitats. Grassland was correlated with forage land, so I selected forage land to use in my models. After preliminary univariate regression analysis and collinearity examinations, six variables were retained to use in building candidate models (Table 2.2). Using the remaining predictor variables, I developed 13 *a priori* candidate models (Table

2.3). Of the 13 *a priori* candidate models evaluated, Model 12 and Model 11 had $\Delta_i < 2$ (Table 2.4). Model 12 ($w_i = 0.54$) (Table 2.5) suggested that pheasant occurrence was associated with a greater amount of forage land, a higher linear density of watercourses, and a higher density of vegetation patches. Model 11 ($w_i = 0.31$) did not contain the linear density of watercourses variable, however this model suggested that pheasant occurrence was associated with a greater amount of forage land and a higher density of vegetation patches. The ROC value for model 12 (0.862) was slightly higher than for model 11 (0.851). Though the top model did not have strong support ($w_i > 0.90$), the beta coefficient estimates were robust across candidate models and therefore model averaging between the 2 models with $\Delta_i < 2$ was unnecessary (Burnham and Anderson 2002). Therefore, I used Model 12 to create a habitat-use map for pheasants (Figure 2.4). When I applied the top AIC model (Model 12) to the study area, areas with high probability of pheasant occurrence often coincided with the EID's current survey routes (Figure 2.4). The pheasant occurrence map also showed that areas of high probability of pheasant occurrence occurred in the central part of the study area.

4.2 Bird Association Model

Forty-nine bird species were heard during the field season (Table 2.6). Species richness ($\beta = 0.210$, $P = 0.031$) was positively associated with pheasant occurrence and the model had good fit (Wald $\chi^2 = 4.68$, $P = 0.031$).

After examination of the screeplot, I determined that the first three principal components sufficiently summarized the bird community data (Figure 2.5). The first principal component (PC1) was characterised by wetland species and its four largest component loadings were Wilson's phalarope (*Phalaropus tricolor*), ruddy duck (*Oxyura jamaicensis*), American coot (*Fulica americana*), and redhead (*Aythya americana*) (Table 2.7). The second principal component (PC2) was characterised by agricultural species and its four largest component loadings were red-winged blackbird (*Agelaius phoeniceus*), American robin (*Turdus migratorius*), mourning dove (*Zenaida macroura*), and ring-billed gull (*Larus delawarensis*) (Table 2.7). The third principal component (PC3) was characterised by native grassland species and its four largest component loadings were willet (*Tringa semipalmata*), vesper sparrow (*Pooecetes gramineus*), horned lark (*Eremophila alpestris*), and Sprague's pipit (*Anthus spragueii*) (Table 2.7). There was a positive association between pheasant occurrence and the wetland component, though it was not significant ($\beta = 0.197$, $P = 0.786$). There was a significant positive association between pheasant occurrence and the agricultural component ($\beta = 2.734$, $P < 0.001$). There was a negative association between pheasant occurrence and the native grassland component, though it was not significant ($\beta = -0.464$, $P = 0.414$). The model describing the relationship between pheasant occurrence and the three principal components had good fit (Wald $\chi^2 = 23.28$, $P < 0.001$) (Table 2.8).

5. DISCUSSION

5.1 Pheasant Occurrence Model

My primary objective was to identify landscape variables that determined the distribution of pheasants in the Eastern Irrigation District. Ecosystems and the animals that inhabit them are complex and rarely does a single feature determine an animal's distribution. The top-ranked model showed that pheasants were associated with greater amounts of forage land, increased linear density of watercourses, and greater density of vegetation patches. Some "clean farming" practices, such as removal of inconvenient patches of brush, remove habitats associated with pheasant occurrence. Therefore, "clean farming" practices might be contributing to the overall decline of pheasants by reducing the amount and quality of habitats for pheasants. The habitat-use map, based on the top-ranked occurrence model, indicated that areas of high pheasant occurrence probability often coincided with the current EID survey routes (Figure 2.4). Thus, these survey routes can be used to monitor the status of the pheasant population in the Eastern Irrigation District. Additional survey routes could be added to monitor for expansion of the pheasant population within the Eastern Irrigation District. If the management objective was to maintain or enhance habitat for pheasants, habitat management should focus on these areas by improving the habitat characteristics associated with pheasant habitat use.

In the Eastern Irrigation District, pheasants were associated with greater amounts of forage land. Forage land, such as alfalfa fields, is important to pheasants because it provides pheasants with a source of spring food (Wagner 1965) and cover for roosting and predator avoidance. Male pheasants establish home ranges in habitats that provide protective cover (Leif 2005). Lachlan and Bray (1976) found that the species composition of the vegetation was not as important as the habitat structure of that vegetation cover. Because females generally nest in tall forage land areas in close proximity to crowing males' territories (Taber 1949, Burger 1966, Dumke and Pils 1979, Ridley and Hill 1987), researchers have suggested that selection of pheasant nesting habitats might be governed by the selection of male territory cover (Gates and Hale 1974, Lachlan and Bray 1976, Robertson et al. 1993). Therefore, enhancement of habitats containing quality cover for male territories, such as forage land areas, might improve overall breeding habitats for pheasants.

Pheasants in this study were associated with greater linear densities of watercourses. Cattails (*Typha* sp.) and other tall vegetation that often surround watercourses can provide protective cover. Pheasants often select annual home ranges with wetlands as the foci (Homan et al. 2003). Wetland habitats are important wintering areas for pheasants because they provide thermal cover and predator protection (Robertson et al. 1993, Gabbert et al. 1999). Both males and females have shown preference for wetland habitat cover during spring (Gates and Hale 1974). Throughout the year, watercourses and their surrounding wetland habitats provide pheasants with water and food sources as well as generally taller habitat structure. Changes in agricultural land-use practices such as draining of wetlands reduce habitat quality for pheasants and could be one of the factors contributing to pheasant population declines.

Not only is the presence of these habitat characteristics important to pheasant habitat selection, but also the density of habitat patches. Pheasants are an edge species and thrive in areas where there is interspersion of food, cover, and display habitats (Yahner 1988). Pheasants prefer to walk not fly and therefore the best habitats occur where important habitat features are in close proximity to one another. The greater the density of vegetation patches in an area, the greater the amount of edge and access to a variety of habitats.

Male pheasants usually perform breeding displays for females in open croplands near the edge of cover. Nonetheless, cropland was not included in any *a priori* candidate models due to preliminary data-reduction procedures. Cultivated grains such as wheat, oats, barley, and canola are important food sources for pheasants (Dalke 1937, Trautman 1952). However, unlike forage land areas, cropland generally does not provide cover for pheasants in spring. Leif (2005) found that pheasants used cropland at relatively low levels during spring because it provided negligible ground cover. Genovesi et al. (1999) found that pheasants used cropland more during summer because by late summer cropland provided both food and cover. These open cropland habitats are important areas for male pheasants to perform their breeding displays as long as protective cover is nearby.

As human demand for agricultural and non-renewable resources increases, the human footprint on this ecosystem likely will increase also. The anthropogenic variables alone and in combination with habitat variables did not describe pheasant occurrence well (Δ AIC ranged from 24.122 to 31.130). Pheasants appear to have adapted well to increased human activities on the landscape and thrive in this highly modified agricultural system.

5.2 Bird Association Model

The presence of pheasants was associated with increased species richness (biodiversity); however, it is only the agricultural bird community that has a significant positive association with pheasants. The agricultural bird community has adapted to coexist with humans in this highly modified landscape. The wetland bird community also is positively associated with pheasants, though not significantly. This positive association is supported by the presence of the watercourses component of the pheasant habitat selection model. The native grassland community has a negative nonsignificant association with pheasants because native grassland species, unlike pheasants, are generally found in native grassland areas that contain minimal amounts of agricultural activity. Conversion of native prairie grassland to agricultural land has resulted in a wildlife community shift from native grassland species to species able to co-exist with humans in the altered agricultural landscape. Riley and Schulz (2001) suggested that ring-necked pheasant populations play a significant role in today's dynamic agricultural landscape by acting as an "ecological barometer" of the health (biodiversity) of our agricultural landscapes. The concept of landscape health is difficult to quantify (Schaeffer et al. 1988), however, several indicators of landscape health, such as biological diversity, sustainability, and ecological resilience, have been identified (Bertollo 2001). Therefore, in my study area, I considered biodiversity as an indicator of landscape health and used avian species richness as a surrogate for biodiversity. Caution must be taken if pheasants are to be used as an ecological indicator of landscape health. Pheasants are not indicators of the avian diversity of native grasslands that existed prior to agricultural land conversion, and can be used only as an indicator of the avian species richness of highly modified agricultural landscapes.

Pheasants are a popular game bird enjoyed for their bright plumage and loud breeding displays. Depending upon management's goals, pheasants might be used to encourage community support and participation in habitat enhancement programs that improve overall habitats in this highly altered agricultural landscape. Other studies have found that passerine populations have benefitted from the implementation of game management programs that improved food and cover resources through active crop plantings (Sage et al. 2005) and maintenance of vegetation strips along crop borders (Stoate 2002). If the objective is to enhance agricultural habitats then using pheasants to encourage community support of habitat enhancement projects may improve projects' chances of success.

6. CONCLUSION

The habitat-use map created based on the RSF model is a useful tool for identifying areas to concentrate management efforts. To continue to monitor the pheasant population trends within the Eastern Irrigation District the sixteen existing crow-count surveys should be surveyed annually. The predictive model developed using resource selection functions provides information regarding pheasant habitat selection in the Eastern Irrigation District. Pheasant habitat management needs to focus on maintaining or enhancing areas of forage land, linear density of watercourses, and density of vegetation patches to provide areas of adequate cover and interspersion of food, cover, and display habitats for pheasants. Because pheasants were associated with areas containing greater amounts of watercourses, draining wetlands is likely to reduce pheasant distribution and abundance. Watercourses and their associated habitats provide pheasants and other bird species with protective and thermal cover. Due to pheasants' need for interspersion of habitats, I recommend that landowners stop mowing roadside ditches adjacent to croplands and stop cultivating inconvenient patches of brush at the corners of crop fields. Leaving standing residual crop on the edges of fields over winter may benefit pheasants in the springtime by providing cover before crops have grown.

Understanding what habitat features are important to pheasants will help land mangers make informed decisions regarding pheasant habitat management in Alberta.

Pheasant habitat management can improve habitat quality for many other agricultural bird species, thereby enhancing agricultural landscape "health." The wetland bird community also might benefit from pheasant habitat management, because pheasants are associated with wetland habitats. The native grassland bird community is negatively associated with pheasants and unfortunately might not benefit from pheasant habitat enhancement, because their habitat requirements generally do not overlap. The native grassland bird community would likely benefit by maintaining or creating native grassland habitat not agricultural habitat.

Table 2.1: Complete list of vegetation and anthropogenic variables used to investigate the distribution of pheasants in the Eastern Irrigation District. Area represents the area of the 600m-radius circular moving window used to generate the GIS variables.

Variable	**Abbreviation**	**Units**	**Category**
Distance to release site	*Dist2relsite*	m	Anthropogenic
House density	*Houseden*	#/area	Anthropogenic
Linear density of pipelines	*Ldpipe*	m/area	Anthropogenic
Linear density of watercourses	*Ldhydro*	m/area	Vegetation
Percent of grassland	*Grass*	%	Vegetation
Percent of cropland	*Crop*	%	Vegetation
Percent of forage land	*Forage*	%	Vegetation
Edge density	*ED*	m/area	Vegetation
Patch density	*PD*	#/area	Vegetation
Contiguity Index	*CI*	#	Vegetation
Contagion	*C*	%	Vegetation
Total Edge	*TE*	m	Vegetation

Table 2.2: Reduced list of vegetation and anthropogenic variables used to understand the distribution of pheasants in the Eastern Irrigation District. Univariate mixed-effects logistic regressions were performed to reduce the number of variables used for modelling and only 6 variables had $P \leq 0.25$. Area represents the area of the 600m-radius circular moving window used to generate the GIS variables.

Variable	Abbreviation	Units	Category
Distance to release site	*Dist2relsite*	m	Anthropogenic
House density	*Houseden*	#/area	Anthropogenic
Linear density of pipelines	*Ldpipe*	m/area	Anthropogenic
Linear density of watercourses	*Ldhydro*	m/area	Vegetation
Percent of forage land	*Forage*	%	Vegetation
Patch density	*PD*	#/area	Vegetation

Table 2.3: *A priori* candidate models used to assess vegetation and anthropogenic variables that influence the distribution of pheasants in the Eastern Irrigation District. See Table 2.1 for variable definitions.

Model Number	**Model Structure**
VEGETATION MODELS	
1	*Forage*
2	*Ldhydro*
3	*Forage + Ldhydro*
ANTHROPOGENIC MODELS	
4	*Ldpipe*
5	*Housede*
6	*Dist2relsite*
7	*Housede + Ldpipe*
8	*Housede + Ldpipe + Dist2relsite*
SPATIAL ARRANGEMENT MODELS	
9	*PD*
VEGETATION & SPATIAL ARRANGEMENT MODELS	
10	*Ldhydro + PD*
11	*Forage + PD*
12	*Forage + Ldhydro + PD*
FULL MODEL	
13	*Forage + Ldhydro + PD + Housede + Dist2relsite + Ldpipe*

Table 2.4: A comparison of *a priori* candidate models used to understand vegetation and anthropogenic variables that determine the distribution of pheasants in the Eastern Irrigation District. Models are ranked by Δ AIC values. Akaike weights (w_i) indicate the probability that the model is the best model given the set of candidate models. K indicates the number of model parameters. Models are described in Table 2.3.

Model	**K**	**AIC**	**Δ AIC**	w_i	**Rank**
12	4	310.490	0	0.538	1
11	3	311.562	1.07	0.315	2
13	7	314.013	3.523	0.092	3
3	3	315.992	5.502	0.034	4
1	2	317.102	6.612	0.020	5
8	4	334.611	24.122	< 0.001	6
7	3	335.300	24.810	< 0.001	7
5	2	335.341	24.852	< 0.001	8
6	2	340.768	30.278	< 0.001	9
4	2	341.620	31.130	< 0.001	10
9	2	341.663	31.173	< 0.001	11
10	3	342.199	31.709	< 0.001	12
2	2	342.735	32.246	< 0.001	13

Table 2.5: Estimated coefficients (β), standard errors (SE), and confidence intervals (CI) for the top-ranked AIC model describing pheasant distribution in the Eastern Irrigation District.

Variable	β	S.E.	95% CI Lower	95% CI Upper
Percent of forage land	4.576	0.833	2.942	6.209
Linear density of watercourses	0.000449	0.000272	-0.0000837	0.000981
Patch density	0.862	0.320	0.236	1.489

Table 2.6: Bird species heard or seen during crow-count surveys in the Eastern Irrigation District and the number of stop points at which each bird species was detected.

Common Name	**Scientific Name**	**Number of Detections**
Canada goose	*Branta canadensis*	232
Gadwall	*Anas strepera*	14
American wigeon	*Anas americana*	5
Mallard	*Anas platyrhynchos*	162
Blue-winged teal	*Anas discors*	2
Northern shoveler	*Anas clypeata*	27
Northern pintail	*Anas acuta*	29
Redhead	*Aythya americana*	5
Lesser scaup	*Aythya affinis*	3
Ruddy duck	*Oxyura jamaicensis*	6
Gray partridge	*Perdix perdix*	27
Grebe	*Podiceps sp.*	5
Great blue heron	*Ardea herodias*	3
Northern harrier	*Circus cyaneus*	7
Swainson's hawk	*Buteo swainsoni*	28
Ferruginous hawk	*Buteo regalis*	3
Rough-legged hawk	*Buteo lagopus*	4
American kestrel	*Falco sparverius*	2
American coot	*Fulica americana*	3
Killdeer	*Charadrius vociferus*	69
American avocet	*Recurvirostra americana*	3
Yellowlegs	*Tringa sp.*	12
Willet	*Tringa semipalmata*	78
Long-billed curlew	*Numenius americanus*	2
Marbled godwit	*Limosa fedoa*	3
Wilson's snipe	*Gallinago delicata*	8
Wilson's phalarope	*Phalaropus tricolor*	5
Ring-billed gull	*Larus delawarensis*	188
Rock pigeon	*Columba livia*	2
Mourning dove	*Zenaida macroura*	80
Great horned owl	*Bubo virginianus*	8
Hairy woodpecker	*Picoides villosus*	5
Eastern kingbird	*Tyrannus tyrannus*	3
Black-billed magpie	*Pica hudsonia*	28
American crow	*Corvus brachyrhynchos*	113
Horned lark	*Eremophila alpestris*	183
American robin	*Turdus migratorius*	55
Gray catbird	*Dumetella carolinensis*	5
European starling	*Sturnus vulgaris*	8
Sprague's pipit	*Anthus spragueii*	42
Vesper sparrow	*Pooecetes gramineus*	81
Longspur	*Calcarius sp.*	14

Table 2.6 (continued)

Common Name	Scientific Name	Number of Detections
Red-winged blackbird	*Agelaius phoeniceus*	240
Western meadowlark	*Sturnella neglecta*	415
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	53
Brewer's blackbird	*Euphagus cyanocephalus*	34
Common grackle	*Quiscalus quiscula*	18
Brown-headed cowbird	*Molothrus ater*	35
House sparrow	*Passer domesticus*	12

Table 2.7: Component loadings for three principal components describing bird communities in the Eastern Irrigation District. The first principal component (PC1) represents the wetland bird community, the second principal component (PC2) represents the agricultural bird community, and the third principal component (PC3) represents the native grassland bird community. Each variable's bolded component loading score represents the highest loading score between all three principal components.

Variable	PC1	PC2	PC3
Canada goose	0.1158	0.1049	**0.2178**
Gadwall	**0.2304**	-0.0060	-0.1352
American wigeon	**0.1592**	-0.0062	-0.3033
Mallard	0.1595	**0.2197**	0.0483
Blue-winged teal	0.0165	**0.0832**	0.0297
Northern shoveler	**0.2605**	-0.0478	-0.0115
Northern pintail	**0.2245**	-0.0638	-0.1790
Redhead	**0.3318**	-0.0812	0.1358
Lesser scaup	**0.0566**	0.0269	-0.0056
Ruddy duck	**0.3685**	-0.0709	0.1421
Gray partridge	0.0174	**0.1619**	-0.0183
Grebe	**0.2121**	-0.0674	-0.3764
Great blue heron	**0.0384**	0.0118	-0.0113
Northern harrier	-0.0023	**0.0584**	-0.0375
Swainson's hawk	-0.0027	**0.0970**	0.0758
Ferruginous hawk	0.0156	-0.0100	**0.0592**
Rough-legged hawk	0.0114	0.0407	**0.0494**
American kestrel	0.0030	0.0215	**0.0712**
American coot	**0.3622**	-0.1077	0.1581
Killdeer	0.0283	**0.2412**	0.0381
American avocet	**0.2772**	-0.1260	-0.0002
Yellowlegs	0.0101	**0.0738**	0.0065
Willet	0.0771	0.0287	**0.3794**
Long-billed curlew	-0.0126	-0.0263	**0.0687**
Marbled godwit	**0.0336**	-0.0211	-0.1004
Wilson's snipe	0.0744	**0.1203**	0.0163
Wilson's phalarope	**0.3892**	-0.1343	-0.2177
Ring-billed gull	0.0360	**0.2637**	0.0839
Rock pigeon	-0.0043	**0.1177**	-0.0825
Mourning dove	-0.0147	**0.2741**	-0.0924
Great horned owl	0.0108	**0.0393**	0.0097
Hairy woodpecker	0.0152	**0.1258**	-0.0219
Eastern kingbird	-0.0050	**0.0076**	-0.0035
Black-billed magpie	0.0588	**0.1417**	0.0388
American crow	0.0871	**0.0879**	0.0781
Horned lark	-0.0158	-0.2247	**0.2441**
American robin	0.0382	**0.3388**	-0.1189
Gray catbird	-0.0070	-0.0197	**0.0112**

Table 2.7 (continued)

Variable	PC1	PC2	PC3
European starling	0.0009	**0.1689**	-0.1083
Sprague's pipit	0.0024	-0.0944	**0.2208**
Vesper sparrow	0.0124	0.0447	**0.2784**
Longspur	-0.0460	-0.0971	**0.1314**
Red-winged blackbird	0.1678	**0.3671**	0.0377
Western meadowlark	0.0695	**0.2152**	0.2018
Yellow-headed blackbird	0.1965	0.0825	**0.2194**
Brewer's blackbird	0.0774	**0.1695**	0.0709
Common grackle	0.0072	**0.2043**	-0.0894
Brown-headed cowbird	-0.0139	**0.1130**	-0.0061
House sparrow	0.0015	**0.2327**	-0.1097

Table 2.8: Model describing the relationship between pheasant occurrence and the three principal components, characterized using principal components analysis. The first principal component (PC1) was characterised by wetland species, the second principal component (PC2) was characterised by agricultural species, and the third principal component (PC3) was characterised by native grassland species. Parameter coefficients (β), standard errors (SE), and confidence intervals (CI) were estimated using mixed-effects logistic regression. The model had good fit (Wald $\chi^2 = 23.28$, $P < 0.001$).

Variable	**β**	**S.E.**	**95% CI**	
			Lower	**Upper**
PC1	0.197	0.724	-1.222	1.615
PC2	2.734	0.628	1.503	3.966
PC3	-0.464	0.568	-1.578	0.649

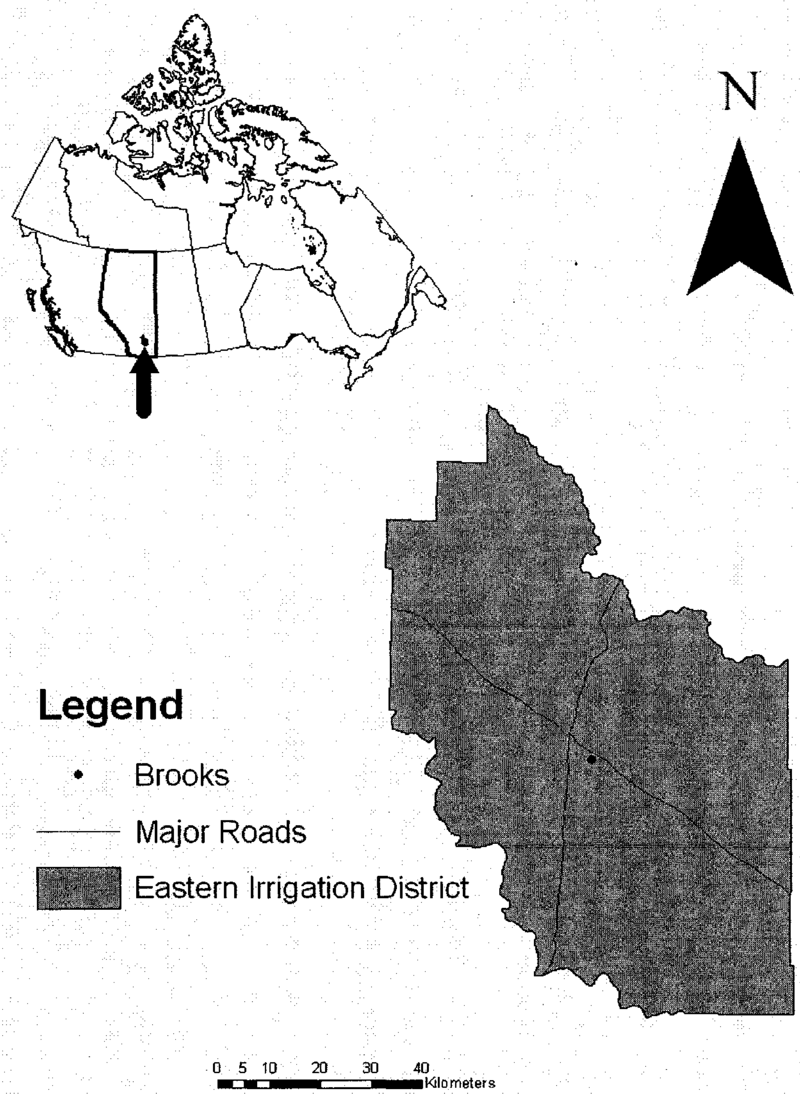

Figure 2.1: Map of the study area (Eastern Irrigation District) located in southeastern Alberta.

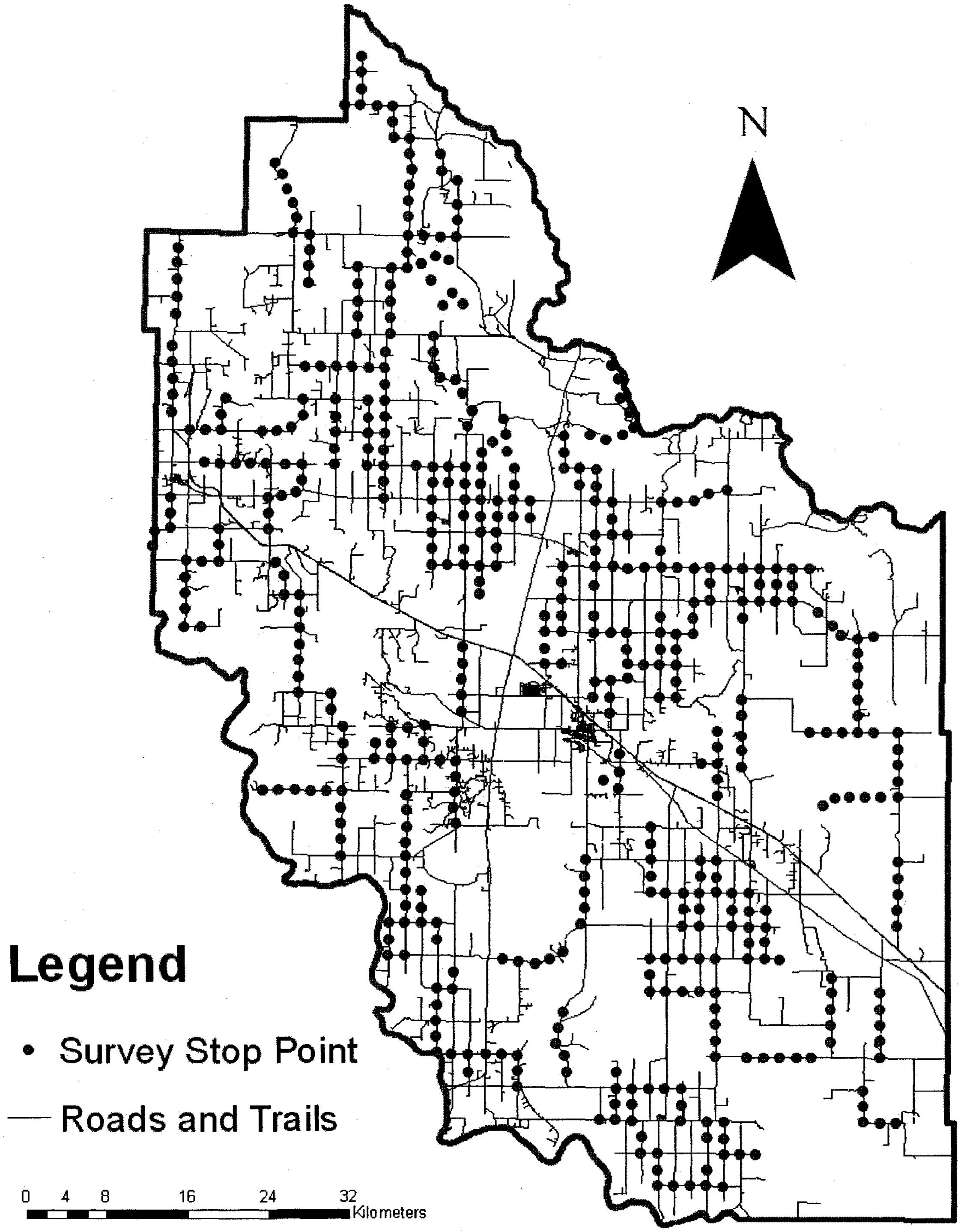

Figure 2.2: Crow-count survey stops within the Eastern Irrigation District.

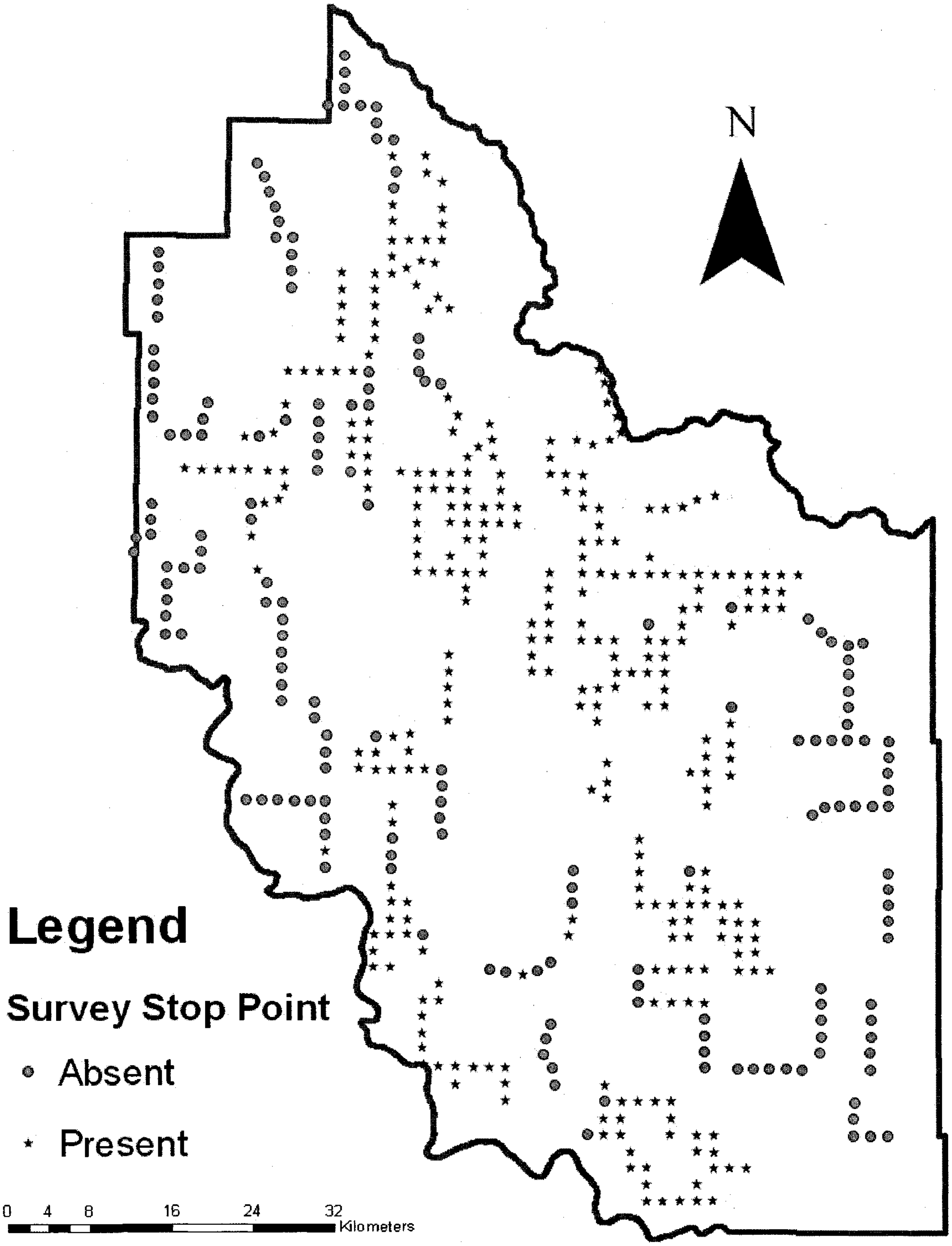

Figure 2.3: Pheasant presence and absence at crow-count survey stops within the Eastern Irrigation District

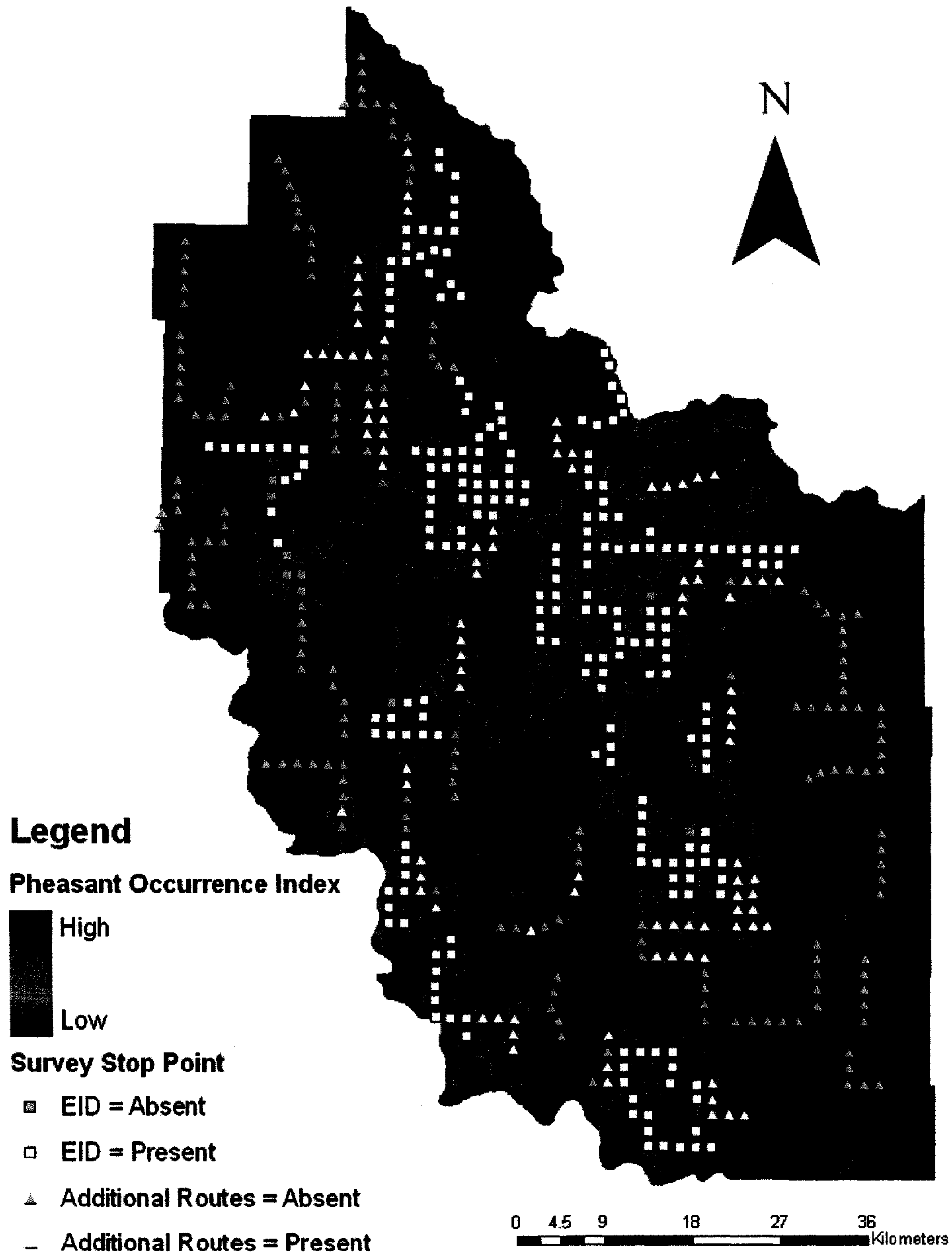

Figure 2.4: Relative index of ring-necked pheasant occurrence within the Eastern Irrigation District overlaid by the crow-count survey stops for both the 16 EID routes (square) and the 54 additional routes (triangle). Stops where ring-necked pheasants are present are colored yellow and stops where they are absent are colored gray. High values (represented by the blue tones) indicate areas where ring-necked pheasants are more likely to be found.

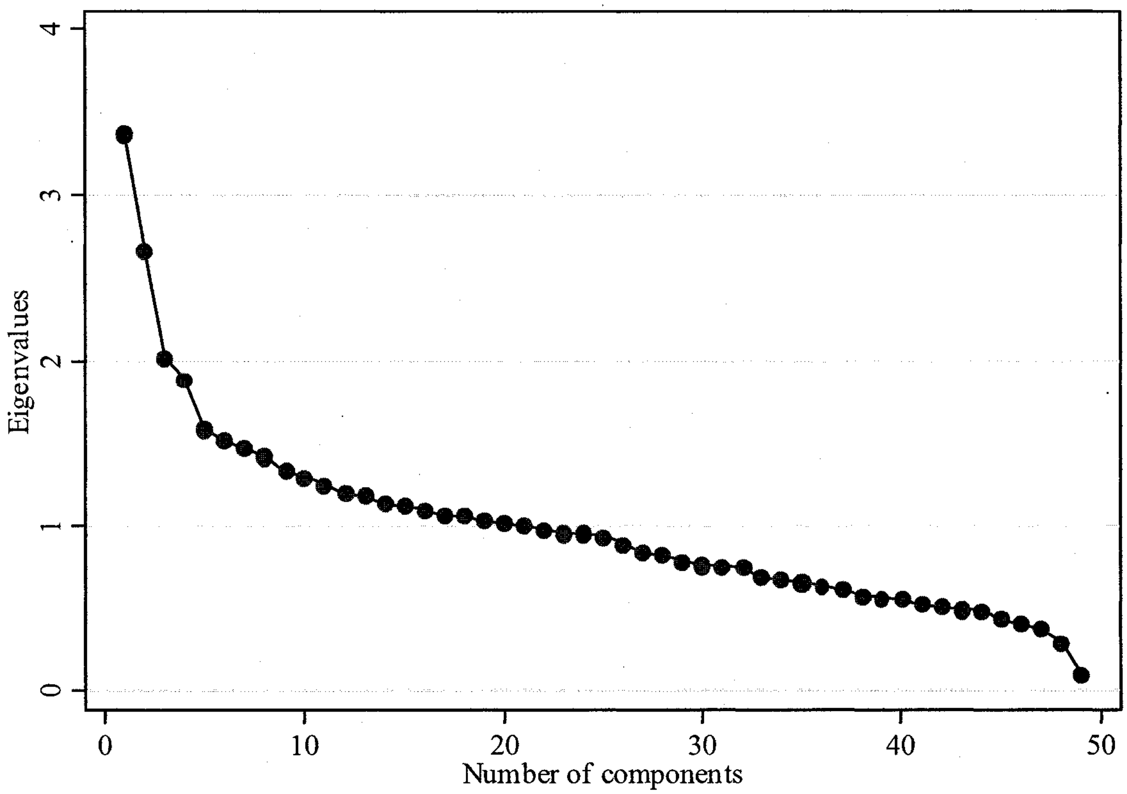

Figure 2.5: Screeplot of eigenvalues versus the number of components used to determine the number of principal components that most effectively characterised the data. There appears to be an inflection point after the third principal component and therefore I chose to use three principal components to explain the variation in the bird community data.

7. LITERATURE CITED

Anderson, D. R., K. P. Burnham, and W. L. Thompson. 2000. Null hypothesis testing: problems, prevalence, and an alternative. Journal of Wildlife Management 64:912–923.

Bender, D. J., T. A. Contreras, and L. Fahrig. 1998. Habitat loss and population decline: a meta-analysis of the patch size effect. Ecology 79:517–533.

Bertollo, P. 2001. Assessing landscape health: a case study from northeastern Italy. Environmental Management 27:349–365.

Boyce, M. S., P. R. Vernier, S. E. Nielsen, and F. K. A. Schmiegelow. 2002. Evaluating resource selection functions. Ecological Modelling 157:281–300.

Burger, G. V. 1966. Observations on aggressive behavior of male ring-necked pheasants in Wisconsin. Journal of Wildlife Management 30:57–64.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer, New York, New York, USA.

Chamberlain, T. C. 1965. The method of multiple working hypotheses. Science 148:754–759.

Clark, W. R., R. A. Schmitz, and T. R. Bogenschutz. 1999. Site selection and nest success of ring-necked pheasants as a function of location in Iowa landscapes. Journal of Wildlife Management 63:976–989.

Dalke, P. L. 1937. Food habits of adult pheasants in Michigan based on crop analysis method. Ecology 18:199–213.

Dumke, R. T., and C. M. Pils. 1979. Re-nesting and dynamics of nest site selection by Wisconsin pheasants. Journal of Wildlife Management 43:705–716.

Endrulat, E. G., S. R. McWilliams, and B. C. Tefft. 2005. Habitat selection and home range size of ruffed grouse in Rhode Island. Northeastern Naturalist 12:411–424.

ESRI. 2005. ArcGIS version 9.1. Environmental Systems Research Institute, Redlands, California, USA.

Gabbert, A. E., A. P. Leif, J. R. Purvis, and L. D. Flake. 1999. Survival and habitat use by ring-necked pheasants during two disparate winters in South Dakota. Journal of Wildlife Management 63:711–722.

Gates, J. M., and J. B. Hale. 1974. Seasonal movement, winter habitat use, and population distribution of an east central Wisconsin pheasant population. Wisconsin Department of Natural Resources Technical Bulletin 76, Madison, Wisconsin, USA.

Genovesi, P., M. Besa, and S. Toso. 1999. Habitat selection by breeding pheasants (*Phasianus colchicus*) in an agricultural area of northern Italy. Wildlife Biology 5:193–201.

Gillies, C. S., M. Hebblewhite, S. E. Nielsen, M. A. Krawchuk, C. L. Aldridge, J. L. Frair, D. J. Saher, C. E. Stevens, and C. L. Jerde. 2006. Application of random effects to the study of resource selection by animals. Journal of Animal Ecology 75:887–898.

Gotelli, N. J., and A. M. Ellison. 2004. A primer of ecological statistics. Sinauer Associates, Sunderland, Massachusetts, USA.

Green, R. H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley & Sons, New York, New York, USA.

Hill, D. A., and M. W. Ridley. 1987. Sexual segregation in winter, spring dispersal and habitat use in the pheasant (*Phasianus colchicus*). Journal of Zoology London 212:657–668.

Hirst, C. N., and D. A. Jackson. 2007. Reconstructing community relationships: the impact of sampling error, ordination approach, and gradient length. Diversity and Distributions 13:361–371.

Homan, H. J., G. M. Linz, and W. J. Bleier. 2000. Winter habitat use and survival of female ring-necked pheasants (*Phasianus colchicus*) in Southeastern North Dakota. American Midland Naturalist 143:463–480.

Homan, H. J., G. M. Linz, R. C. Carlson, and W. J. Bleier. 2003. Spring distribution of ring-necked pheasants (*Phasianus colchicus*) following cattail reduction with glyphosate herbicide. Wildlife Research 30:159–166.

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

Johnson, C. J., S. E. Nielsen, E. H. Merrill, T. L. McDonald, and M. S. Boyce. 2006. Resource selection functions based on use-availability data: theoretical motivation and evaluation methods. Journal of Wildlife Management 70:347–357.

Kimball, J. W. 1949. The crowing count pheasant census. Journal of Wildlife Management 13:101–120.

Lachlan, C., and R. P. Bray. 1976. Habitat selection by cock pheasants in the spring.

Journal of Applied Ecology 13:691–704.

Leopold, A. 1933. Game management. Charles Scribner, New York, USA.

Leif, A. P. 2005. Spatial ecology and habitat selection of breeding male pheasants. Wildlife Society Bulletin 33:130–141.

Manly, B. F. J. 1992. The design and analysis of research studies. Cambridge University Press, Cambridge, UK.

Manly, B. F. J., L. L. McDonald, D. L. Thomas, T. L. McDonald, and W. P. Erickson. 2002. Resource selection by animals: statistical design and analysis for field studies. Kluwer, Dordrecht, The Netherlands.

McGarigal, K., S. A. Cushman, M. C. Neel, and E. Ene. 2002. FRAGSTATS: Spatial pattern analysis program for categorical maps [software]. http://www.umass.edu/landeco/research/fragstats/fragstats.html

McKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Elsevier Academic Press, Burlington, Massachusetts, USA.

Meyers, S. M., J. A. Crawford, T. F. Haensly, and W. J. Castillo. 1988. Use of cover types and survival of ring-necked pheasant broods. Northwest Science 62:36–40.

Ridley, M. W., and D. A. Hill. 1987. Social organization in the pheasant (*Phasianus colchicus*): harem formation, mate selection, and the role of mate guarding. Journal of Zoology 211:619–630.

Riley, T. Z., and J. H. Schulz. 2001. Predation and ring-necked pheasant population dynamics. Wildlife Society Bulletin 29:33–38.

Robbins, C. S. 1981. Bird activity levels related to weather. Pages 301–310 *in* C.J. Ralph, and S.J. Michael, editors. Estimating the numbers of terrestrial birds: proceedings of an international symposium held at Asilomar, California, October 26–31, 1980. Studies in Avian Biology, Number 6. Allen Press, Lawrence, Kansas, USA.

Robertson, P. A. 1996. Does nesting cover limit abundance of ring-necked pheasant in North America? Wildlife Society Bulletin 24:98–106.

Robertson, P. A., M. I. A. Woodburn, W. Neutel, and C. E. Bealey. 1993. Effects of land use on breeding pheasant density. Journal of Applied Ecology 30:465–477.

Sage, R. B., D. M. B. Parish, M. I. A. Woodburn, and P. G. L. Thompson. 2005.

Songbirds using crops planted on farmland as cover for game birds. European Journal of Wildlife Research 51:248–253.

Sauer, J. R., J. E. Hines, and J. Fallon. 2005. The North American Breeding Bird Survey, Results and Analysis 1966–2004. Version 2005.2. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Schaeffer, D. J., E. E. Herricks, and H. W. Kerster. 1988. Ecosystem health: measuring ecosystem health. Environmental Management 12:445–455.

STATA. 2005. Stata Statistical Software: Version 9.1. College Station, Texas, USA.

Statistics Canada. 2002. 2001 Community Profiles. Statistics Canada Catalogue no. 93F0053XIE.

Statistics Canada. 2006. 2006 Census of Agriculture, Farm Data and Farm Operator Data. Statistics Canada Catalogue no. 95-629-XWE.

Stoate, C. 2002. Multifunctional use of a natural resource on farmland: wildlife pheasant (*Phasianus colchicus*) management and the conservation of farmland passerines. Biodiversity and Conservation 11:561–573.

Taber, R. D. 1949. Observations on the breeding behavior of the ring-necked pheasant. Condor 51:153–175.

Trautman, C. G. 1952. Pheasant food habits in South Dakota and their economic significance to agriculture. South Dakota Department of Wildlife, Parks, and Forestry Technical Bulletin 1, Pierre, South Dakota, USA.

Wagner, F. H. 1965. Population ecology and management of Wisconsin pheasants. Wisconsin Conservation Department Technical Bulletin 34:162–168.

Warner, R. E., P. Hubert, P. C. Mankin, and C. A. Gates. 2000. Disturbance and the survival of female ring-necked pheasants in Illinois. Journal of Wildlife Management 64:663–672.

Yahner, R. H. 1988. Changes in wildlife communities near edges. Conservation Biology 2:333–339.

CHAPTER 3

RING-NECKED PHEASANT (*Phasianus colchicus*) ABUNDANCE IN SOUTHEASTERN ALBERTA

1. INTRODUCTION

Abundance of a species in an area may be influenced by natural (vegetation structure, seasonal variation) or anthropogenic factors (habitat removal, traffic volume). Changes in abundance may significantly impact ecosystem health and human economic interests. Therefore, it is important to understand what factors influence species abundance so that effective management strategies can be developed to properly address changes in abundance.

Since the late 1970's, ring-necked pheasants (*Phasianus colchicus*) have been declining throughout their North American range (Dahlgren 1988, Sauer et al. 2005). Changes in agricultural land-use practices have been speculated to be one of the factors responsible for their decline (Robertson et al. 1993b). Larger areas of monoculture and "clean farming" practices reduce food, cover, and interspersion of habitats for pheasants (Brown 1941, Warner 1994, Warner 1999). Previous studies have found that ring-necked pheasant abundance is related to habitat features such as the amount of woodland edge and standing cover (Jarvis and Simpson 1978, Robertson et al. 1993a, Robertson et al. 1993b, Robertson 1996). Knowledge of abundance patterns can provide critical insight into a species' ecological requirements and enhance our understanding of factors influencing the number of individuals.

To manage species effectively, we need to understand the link between species occurrence and abundance (Nielsen et al. 2005, Ripley et al. 2005). In the previous chapter, I explored the relationship between pheasant occurrence and vegetation and anthropogenic landscape features. The next step is to understand the link between occurrence and abundance (Nielsen et al. 2005, Ripley et al. 2005). Do the same characteristics that influence pheasant occurrence also play a role in abundance? My specific objectives were to: (1) examine the strength of the correlation between predicted probability of occurrence and observed pheasant abundance, and (2) identify vegetation and anthropogenic features associated with pheasant abundance. Understanding the relationship between occurrence and abundance and identifying the factors that influence pheasant abundance will provide information that land managers can use to make informed management decisions.

2. STUDY AREA

The study was located in the Eastern Irrigation District (EID), which is centred on Brooks, Alberta (Figure 3.1). The EID encompassed 6,000 km^2 bounded by the Bow River to the north and the Red Deer River to the south. This region in southeastern Alberta was composed of native prairie, farmland, oil and gas activity, and irrigation facilities. The EID provided irrigation to approximately 1,100 km^2 of cultivated cropland. Over 30,000 oil and gas wells were present within the study area. The Canadian Pheasant Company located in Brooks raised and released pheasants during the fall hunting season.

3. METHODS

3.1 Data Collection

Crow-count surveys were performed during April and May 2006 following the same methods as outlined in Chapter 2. During each survey the number of males heard and observed crowing as well as the estimated distance to each crowing male was recorded. All stop points were sampled three times. The mean pheasant abundance (average number of pheasants heard over the three sampling occasions) and maximum pheasant abundance at each stop point were highly correlated ($r = 0.948$, $P < 0.001$). Because the negative binomial statistical framework uses a count response variable, I used the maximum number of pheasants counted at each stop point in any of the three sampling occasions as the index of pheasant abundance. Stop points with no pheasants heard during all three sampling occasions were specified as zero. The vegetation and anthropogenic predictor variables described in Chapter 2 also were used in this analysis of abundance (Table 3.1).

3.2 Pheasant Abundance Model

All predictor variables were examined for outliers prior to model development. I evaluated the 13 *a priori* candidate models outlined in Chapter 2, but with maximum pheasant abundance as the response variable.

I evaluated the relationship between the predicted probability of occurrence (obtained from the top AIC occurrence model in Chapter 2) and pheasant abundance using Pearson's correlations and graphical methods.

I used zero-inflated negative binomial (ZINB) regression to assess the effects of habitat and anthropogenic features on the relative abundance of pheasants. Negative binomial regression (NB) is a statistical framework that can be used to analyse abundance data. However, abundance data often includes a prevalence of zero counts (Southwood and Henderson 2000). The excess of zeros in count data often result in the data being overdispersed relative to the negative binomial distribution. Zero-inflated negative binomial models have been developed to deal with the problem of overdispersion due to excessive zeros in the data. The zero-inflated model considers that the zero data is a result of two discrete processes: "Always Zero" group and "Not Always Zero" group (Long and Freese 2006). The "Always Zero" group is analysed using a logit model and is referred to as the inflation group. The "Not Always Zero" group is modelled following the negative binomial distribution. I plotted the distribution of the pheasant abundance data to confirm that it followed the negative binomial distribution (Hilborn and Mangel 1997). I used the top-ranked AIC-selected occurrence model from Chapter 2 as the inflation group for my abundance analysis (Nielsen et al. 2005, Ripley et al. 2005).

I calculated the variance to mean ratio as a method of determining if the pheasant count data were overdispersed. Ratios greater than 1 indicate overdispersion. I also used the Vuong test to determine if the zero-inflated version was required when modelling the data (Vuong 1989). The Vuong test compares the ZINB to the regular NB and a significant result indicates that the zero-inflated version should be used.

I also wanted to confirm that the ZINB model was the appropriate framework to use instead of zero-inflated Poisson (ZIP) model. Therefore, I used a likelihood ratio test to compare ZINB and ZIP models since the ZIP and ZINB models are nested (Long 1997). A significant result provides evidence for the use of the ZINB over the ZIP.

To account for the lack of independence between my stop points along each route, I used the robust cluster option in STATA (Rogers 1993, Long and Freese 2006). The robust cluster method uses the Huber-White sandwich estimator to inflate the variance of the coefficient estimates (White 1980).

AIC was used to select the most parsimonious candidate model explaining the abundance of pheasants (Burnham and Anderson 2002). I calculated the predicted probability of each pheasant count using the top AIC-selected ZINB and ZIP models and plotted them against the observed frequency of each pheasant count to visually evaluate model fit (Nielsen et al. 2005, Long and Freese 2006). I statistically evaluated model fit using the Wald χ^2 statistic. All analyses were conducted in STATA 9.1 (STATA 2005).

I used RSF scores to determine if pheasant release sites were placed in habitats that pheasants would likely occur in. I categorised the pheasant habitat-use map, based on the most parsimonious pheasant occurrence model in Chapter 2, into 8 bins of RSF scores ranging from 0 to 7. The higher the RSF score the higher the probability of a pheasant occurring at that location.

4. RESULTS

Of the 498 stop points surveyed, 180 stops (36%) had zero pheasants detected. Pheasant crow counts at the remaining 318 (64%) stops ranged between 1 and 25.

The predicted probability of occurrence obtained from the top occurrence model from Chapter 2 was positively correlated with pheasant abundance ($r = 0.223$, $P < 0.001$), although the relationship is burdened by high variance (Figure 3.2).

After visual inspection of the data and a calculated variance to mean ratio of 6.19, I concluded that a zero-inflated model was needed to model my data. The Vuong test for all models was significant ($P < 0.001$) also, which provided additional support for the use of zero-inflated models. After a significant likelihood ratio test ($G^2 = 380.80$, $P < 0.001$) and visual inspection of the data, I concluded that the ZINB regression model should be used to analyse my data because it provided a better fit than the ZIP model. The inflation portion for all ZINB models was the top-ranked occurrence model from Chapter 2 that included the amount of forage land, the linear density of watercourses, and the density of vegetation patches.

Thirteen *a priori* candidate models were compared using AIC and only one model had an AIC difference (Δ_i) less than 2 (Table 3.2). This top-ranked model indicated that the frequency of pheasant crow counts was positively related to distance from pheasant release sites ($\beta = 0.0000284$, $P < 0.005$) (Figure 3.3). I visually and statistically inspected the fit of the top-ranked model to the data and found that the ZINB model provided a good visual fit (Figure 3.4) and was statistically significant (Wald $\chi^2 = 9.28$, $P < 0.005$).

The average RSF score for the pheasant release sites was 5.6, so I concluded that the release sites were placed in good pheasant habitat (Figure 3.5).

5. DISCUSSION

Understanding the connection between pheasant occurrence and abundance enhanced our knowledge of pheasant populations within the Eastern Irrigation District. Nielsen et al. (2005) found that occurrence and abundance often exhibit a general positive pattern but are not necessarily closely tied. In my study there was a positive relationship between the predicted probability of occurrence and pheasant abundance, but the relationship was burdened by high variance. This suggested that factors responsible for determining occurrence were not the same ones that determined abundance. Occurrence models indicated that pheasant occurrence was positively associated with vegetation features that consisted of the amount of forage land, linear density of watercourses, and density of vegetation patches. On the other hand, I found that vegetation features were not as good for predicting pheasant abundance as was the distance to the nearest pheasant release site. Management plans need to consider factors that influence both occurrence and abundance to effectively manage pheasants.

Pen-reared pheasants are primarily released within the study area to supplement the wild pheasant population during the fall hunting season. However, no studies have looked at the direct effect of released pheasants on wild populations. Previous studies generally considered the survival, reproductive productivity, dispersal rate from release sites, and predators of released pheasants (Jarvis and Engbring 1976, Haensly et al. 1985, Krauss et al. 1987, Robertson 1988, Hill and Robertson 1988, Leif 1994, Kenward et al. 2001). Studies even compared released and wild birds and found that released birds had lower reproductive output and survival than wild birds (Hill and Robertson 1988, Leif 1994), but no study investigated the impact of released birds on wild pheasant populations. This research topic requires immediate attention because pheasants are routinely released to supplement wild populations and the ecological consequences of this practice is unknown.

Previous pheasant studies have found that pheasant abundance was related to vegetation features (Jarvis and Simpson 1978, Robertson et al. 1993a, Robertson et al. 1993b, Robertson 1996). In my study area, vegetation features, such as amount of forage land, linear density of watercourses, and density of vegetation patches, were good predictors of pheasant distribution but were not as important for predicting pheasant abundance as was distance to release sites. Pheasant abundance was positively associated with distance to pheasant release sites indicating that, even though release sites were placed in good pheasant habitat, releasing pheasants might make the fall release sites unfavourable areas for wild pheasants. At least two competing hypotheses could explain why more pheasants are found farther from release sites. First, intense hunting pressure at release sites may be depleting both released and wild stocks in those areas, resulting in lower spring crow counts near release sites. Previous pheasant studies have found that release sites experience intense concentrated hunting pressure with hunters harvesting between 50-88% of released male pheasants (Burger 1964, Stokes 1968, Burger and Oldenburg 1972, Jarvis and Engbring 1976, Diefenbach et al. 2000). Other studies have found that intense hunting pressure may result in a large amount of mortality (Fleskes et al. 2007) and thus reduces game bird abundance (Thiollay 2005). Second, the majority of released pheasants (93-96%) disperse less than 1 mile from release sites (Burger 1964, Wilson et al. 1992, Leif 1994) and therefore, released birds might displace wild birds from release site areas, though no research has examined the effect of released birds on wild populations. Because released birds have lower (overwinter) survival than wild birds (Jarvis and Engbring 1976, Krauss 1987, Brittas et al. 1992, Diefenbach et al. 2000), lower pheasant abundance would result near release sites if the wild pheasant population was indeed displaced by the released birds. Additional research needs to be done to investigate why more pheasants are found farther away from pheasant release sites.

Wild pheasants in the vicinity of release sites need to be monitored to address whether reduced pheasant abundance near release sites is due to hunting pressure or displacement of wild pheasants by released birds. Prior to the fall hunting season, wild pheasants should be captured near release sites and fitted with radiotransmitters. Radiotransmitters also should be put on a percentage of released pheasants in those areas. Movements, interactions, mortality, and survival of both released and wild pheasants should be monitored. If research findings determine that wild populations are being reduced near release sites due to extreme hunting pressure, managers will need to consider potentially changing hunting practices as a means of maintaining wild pheasant populations near release sites. If research findings indicate that released pheasants are displacing wild pheasants and indeed do have lower survival than wild pheasants, I would argue against pheasant release programs because wild stocks survive better. If this is the case then perhaps efforts to increase wild pheasant populations should be directed towards improving pheasant habitats instead of releasing pheasants.

6. CONCLUSION

The highly variant positive relationship between pheasant occurrence and abundance suggested that different factors might be responsible for determining occurrence and abundance. Distance from release sites appears to be more important than vegetation or other anthropogenic features in determining spring pheasant abundance. Although release sites are placed in good pheasant habitat, releasing pheasants might make these locations unfavourable for wild pheasants. Other studies have focused on released pheasants' survival, reproductive productivity, dispersal rate from release site, and predation rate, however, none have considered the impact of released birds on the wild pheasant population. More research is needed to investigate the effect of releasing pheasants on wild pheasant populations within the Eastern Irrigation District.

Table 3.1: List of vegetation and anthropogenic variables (described in chapter 2) used to understand the abundance of pheasants in the Eastern Irrigation District. Area represents the area of the 600m-radius circular moving window used to generate the GIS variables.

Variable	**Abbreviation**	**Units**	**Category**
Distance to release site	*Dist2relsite*	m	Anthropogenic
House density	*Houseden*	#/area	Anthropogenic
Linear density of pipelines	*Ldpipe*	m/area	Anthropogenic
Linear density of watercourses	*Ldhydro*	m/area	Vegetation
Percent of forage land	*Forage*	%	Vegetation
Patch density	*PD*	#/area	Vegetation

Table 3.2: Zero-inflated negative binomial regression models used to predict pheasant abundance within the Eastern Irrigation District. Thirteen *a priori* candidate models were compared using AIC values. Akaike weights (w_i) indicate the weight of evidence that any particular model is the best model given the set of candidate models. K specifies the number of model parameters. See Table 3.1 for variable definitions.

Model #	Model Structure	K	AIC	Δ AIC	w_i	Rank
6	*Dist2relsite*	2	2089.908	0	0.832	1
13	*Forage + Ldhydro + PD + Houseden + Dist2relsite + Ldpipe*	7	2093.428	3.52	0.143	2
8	*Houseden + Ldpipe + Dist2relsite*	4	2096.932	7.024	0.025	3
9	*PD*	2	2106.864	16.956	< 0.001	4
11	*Forage + PD*	3	2108.624	18.716	< 0.001	5
10	*Ldhydro + PD*	3	2108.784	18.876	< 0.001	6
12	*Forage + Ldhydro + PD*	4	2110.584	20.676	< 0.001	7
5	*Houseden*	2	2112.242	22.334	< 0.001	8
1	*Forage*	2	2112.46	22.552	< 0.001	9
4	*Ldpipe*	2	2112.472	22.564	< 0.001	10
2	*Ldhydro*	2	2112.476	22.568	< 0.001	11
7	*Houseden + Ldpipe*	3	2114.238	24.33	< 0.001	12
3	*Forage + Ldhydro*	3	2114.458	24.55	< 0.001	13

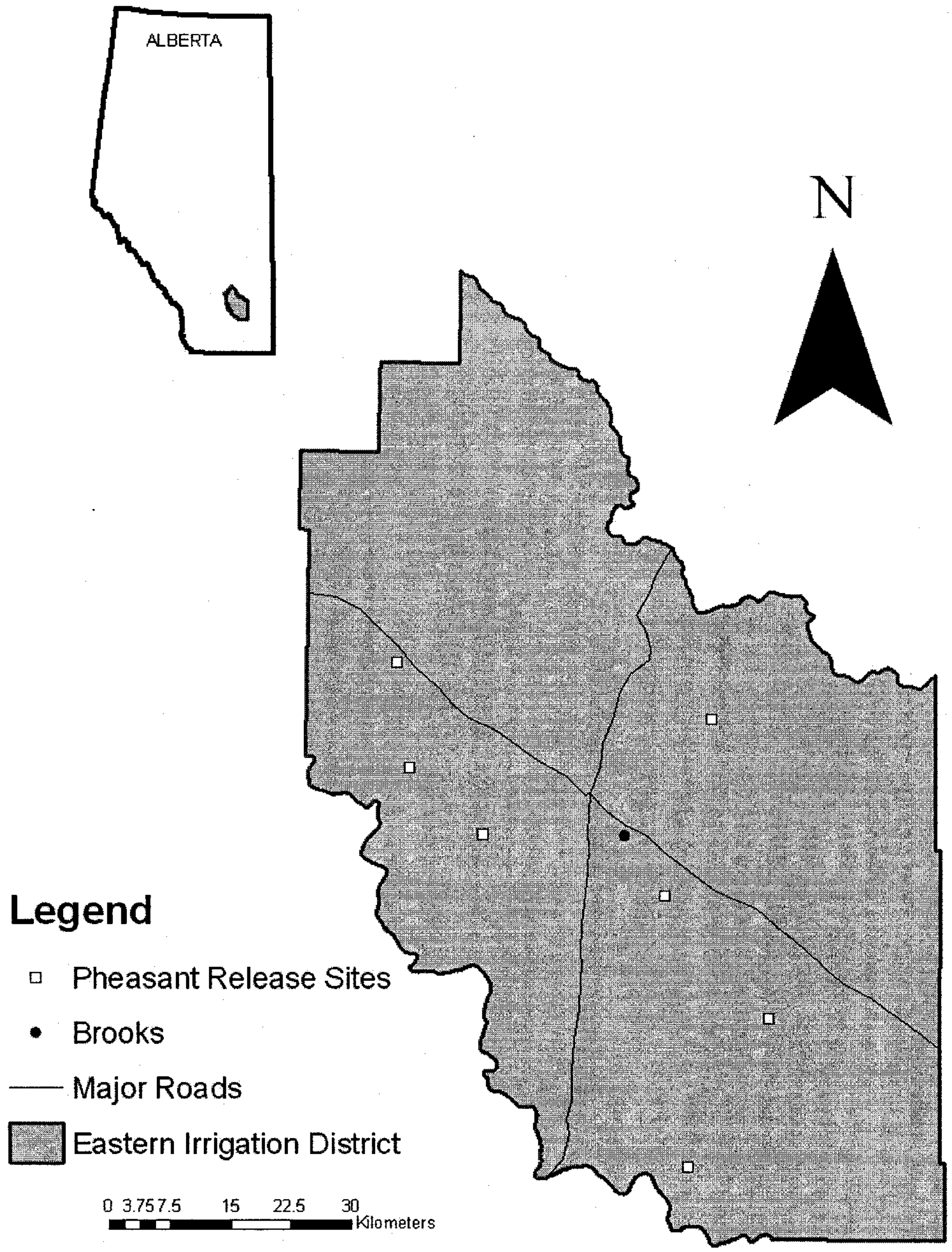

Figure 3.1: Map of the study area in southeastern Alberta. The study was conducted in the Eastern Irrigation District.

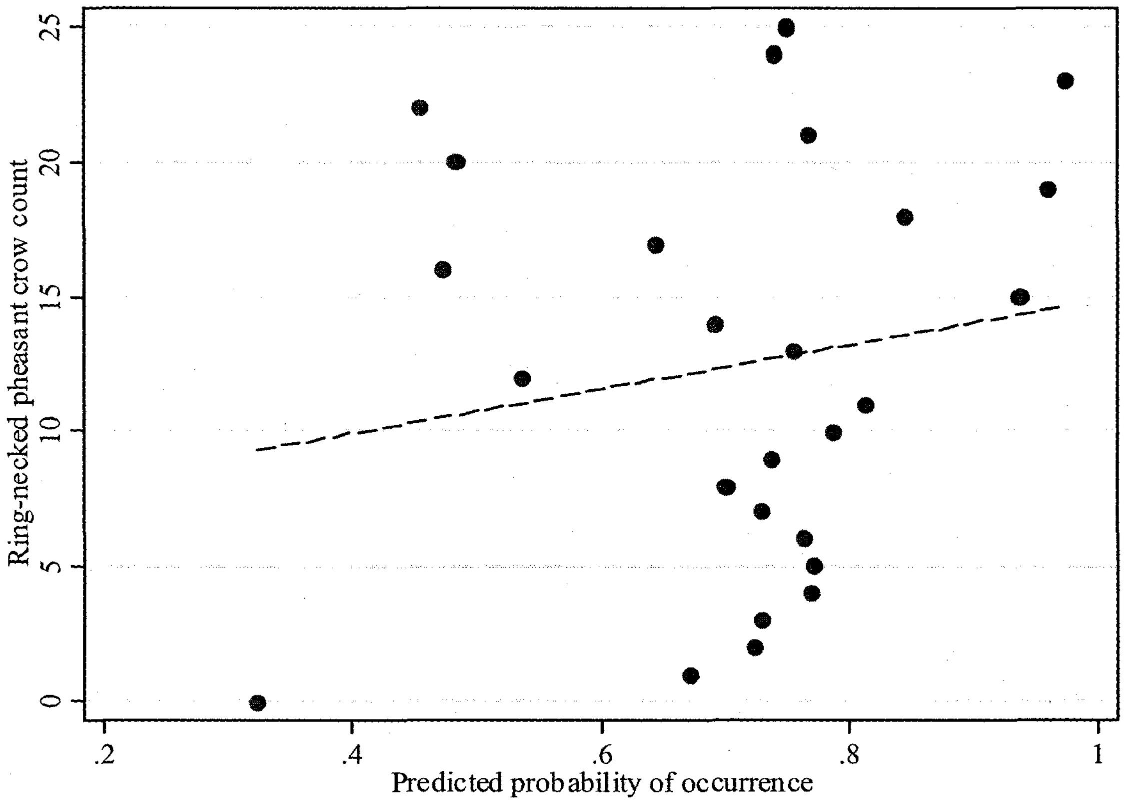

Figure 3.2: Crow counts of ring-necked pheasants at survey stop points versus the mean predicted probability of occurrence based on a resource selection probability function. The top occurrence model from chapter 2 was used to generate the predicted probability of occurrence. The predicted probability of occurrence was positively correlated with the frequency of pheasant crow counts in spring ($r = 0.223$, $P < 0.001$).

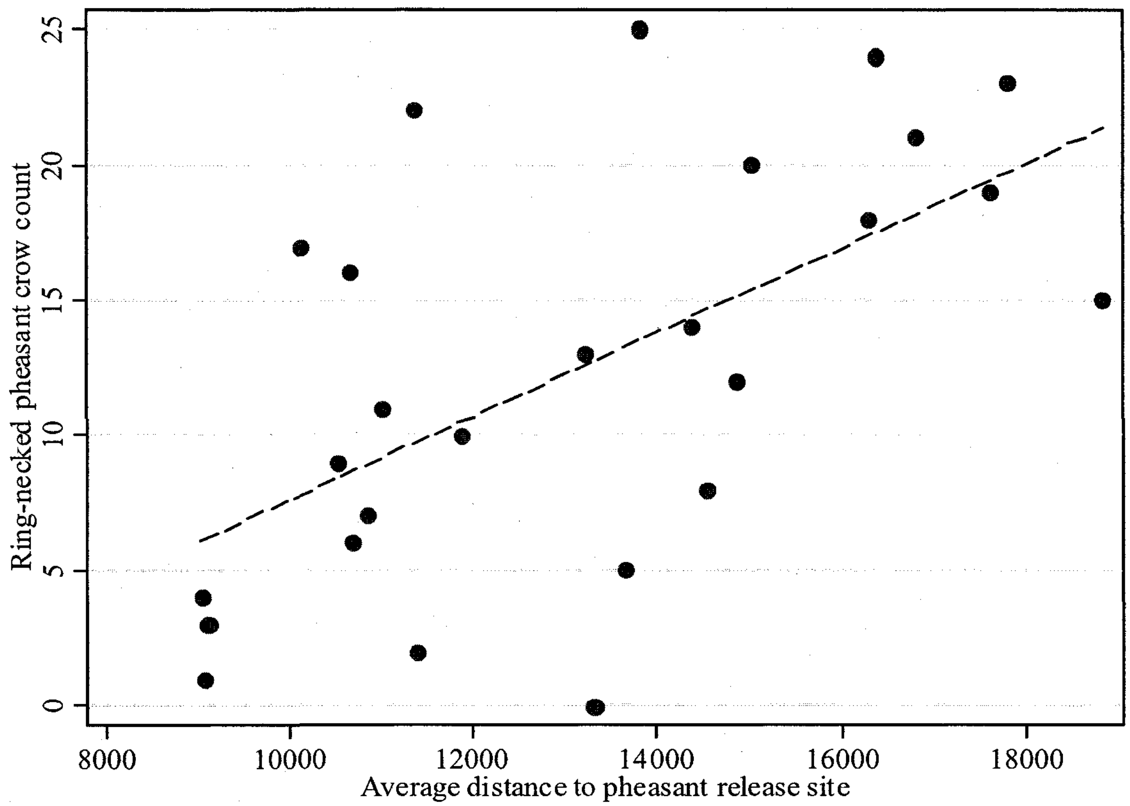

Figure 3.3: Maximum crow counts of ring-necked pheasants at survey stop points in spring versus the average distance (m) to fall release site ($r = 0.594$, $P < 0.001$).

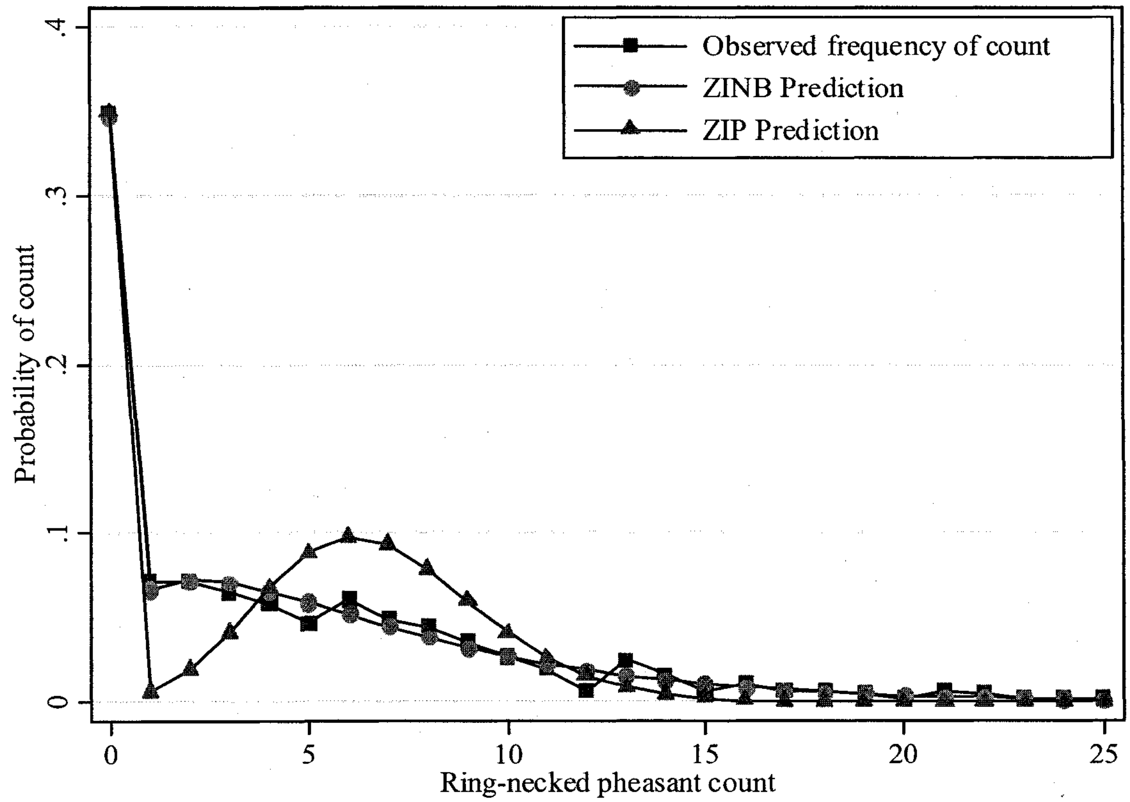

Figure 3.4: Zero-inflated negative binomial (ZINB) and Poisson (ZIP) model predictions plotted against the observed pheasant crow count frequency illustrating model fit. The ZINB provides the closest fit to the data.

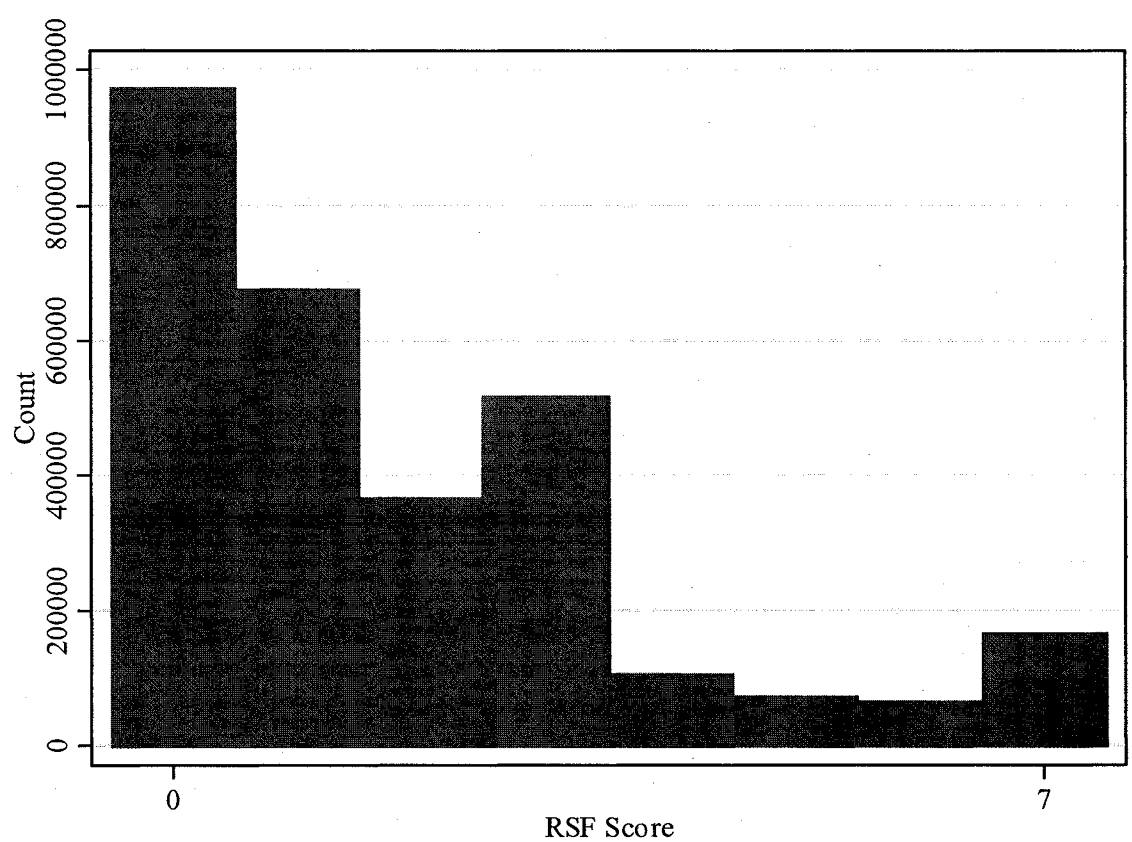

Figure 3.5: Frequency of ring-necked pheasant RSF bin scores. I reclassified the pheasant habitat-use map from Chapter 2 into 8 bins of RSF scores ranging from 0 to 7. The higher the RSF score the higher the probability of a pheasant occurring at that location. The pheasant release sites had an average RSF score of 5.6, indicating that release sites were placed in good pheasant habitat.

7. LITERATURE CITED

Brittas, R., V. Marcström, R. E. Kenward, and M. Karlbom. 1992. Survival and breeding success of reared and wild ring-necked pheasants in Sweden. Journal of Wildlife Management 56:368–376.

Brown, L. 1941. The management of farm wildlife. Transactions of the Kansas Academy of Science 44:381–388.

Burger, G. V. 1964. Survival of ring-necked pheasants released on a Wisconsin shooting preserve. Journal of Wildlife Management 28:711–721.

Burger, G. V., and R. C. Oldenburg. 1972. Using pheasant band recoveries to evaluate habitat on shooting preserves. Journal of Wildlife Management 36:146–149.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer, New York, New York, USA.

Dahlgren, R. B. 1988. Distribution and abundance of the ring-necked pheasant in North America. Pages 29–43 *in* D. L. Hallett, W. R. Edwards, and G. V. Burger, editors. Pheasants: symptoms of wildlife problems on agricultural lands. North Central Section of The Wildlife Society, Bloomington, Indiana, USA.

Diefenbach, D. R., C. F. Riegner, and T. S. Hardisky. 2000. Harvest and reporting rates of game-farm ring-necked pheasants. Wildlife Society Bulletin 28:1050–1059.

Fleskes, J. P., J. L. Yee, G. S. Yarris, M. R. Miller, and M. L. Casazza. 2007. Pintail and mallard survival in California relative to habitat, abundance, and hunting. Journal of Wildlife Management 71:2238–2248.

Haensly, T. F., S. M. Meyers, J. A. Crawford, and W. J. Castillo. 1985. Treatments affecting post-release survival and productivity of pen-reared ring-necked pheasants. Wildlife Society Bulletin 13:521–528.

Hilborn, R., and M. Mangel. 1997. The ecological detective: confronting models with data. Princeton University Press, Princeton, New Jersey, USA.

Hill, D., and P. Robertson. 1988. Breeding success of wild and hand-reared ring-necked pheasants. Journal of Wildlife Management 52:446–450.

Jarvis, R. L., and J. Engbring. 1976. Survival and reproduction of wild game-farm pheasants in Western Oregon. Northwest Science 50:222–230.

Jarvis, R. L., and S. G. Simpson. 1978. Habitat, survival, and abundance of pheasants in Western Oregon, 1947–1975. Journal of Wildlife Management 42:866–874.

Kenward, R. E., D. G. Halls, S. S. Walls, and K. H. Hodder. 2001. Factors affecting predation by buzzards *Buteo buteo* on released pheasants *Phasianus colchicus*. Journal of Applied Ecology 38:813–822.

Krauss, G. D., H. B. Graves, and S. M. Zervanos. 1987. Survival of wild and game-farm cock pheasants released in Pennsylvania. Journal of Wildlife Management 51:555–559.

Leif, A. P. 1994. Survival and reproduction of wild and pen-reared ring-necked pheasants. Journal of Wildlife Management 58:501–506.

Long, J. S. 1997. Regression models for categorical and limited dependent variables. Sage Publications, Thousand Oaks, California, USA.

Long, J. S., and F. Freese. 2006. Regression models for categorical dependent variables using Stata. Stata Press, College Station, Texas, USA.

Nielsen, S. E., C. J. Johnson, D. C. Heard, and M. S. Boyce. 2005. Can models of presence-absence be used to scale abundance? Two case studies considering extremes in life history. Ecography 28:197–208.

Ripley, T., G. Scrimgeour, and M. S. Boyce. 2005. Bull trout (*Salvelinus confluentus*) occurrence and abundance influenced by cumulative industrial developments in a Canadian boreal forest watershed. Canadian Journal of Fisheries and Aquatic Sciences 62:2431–2442.

Robertson, P. A. 1996. Does nesting cover limit abundance of ring-necked pheasant in North America? Wildlife Society Bulletin 24:98–106.

Robertson, P. A., M. I. A. Woodburn, and D. A. Hill. 1993a. Factors affecting winter pheasant density in British woodlands. Journal of Applied Ecology 30:459–464.

Robertson, P. A., M. I. A. Woodburn, W. Neutel, and C. E. Bealey. 1993b. Effects of land use on breeding pheasant density. Journal of Applied Ecology 30:465–477.

Robertson, P. A. 1988. Survival of released pheasants, *Phasianus colchicus*, in Ireland. Journal of Zoology 214:683–695.

Rogers, W. H. 1993. Regression standard errors in clustered samples. Stata Technical Bulletin 13:19–23.

Sauer, J. R., J. E. Hines, and J. Fallon. 2005. The North American Breeding Bird Survey, Results and Analysis 1966–2004. Version 2005.2. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Southwood, T. R. E., and P. A. Henderson. 2000. Ecological methods. Third edition. Blackwell Science, Oxford, UK.

STATA. 2005. Stata Statistical Software: Version 9.1. College Station, Texas, USA.

Stokes, A. W. 1968. An eight-year study of a northern Utah pheasant population. Journal of Wildlife Management 32:867–874.

Thiollay, J. M. 2005. Effects of hunting on Guianan forest game birds. Biodiversity and Conservation 14:1121–1135.

Vuong, Q. H. 1989. Likelihood ratio tests for model selection and non-nested hypotheses. Econometrica 57:307–333.

Warner, R. E. 1994. Agricultural land use and grassland habitat in Illinois: future shock for midwestern birds? Conservation Biology 8:147–156.

Warner, R. E., P. C. Mankin, L. M. David, and S. L. Etter. 1999. Declining survival of ring-necked pheasant chicks in Illinois during the late 1900s. Journal of Wildlife Management 63:705–710.

White, H. 1980. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. Econometrica 48:817–838.

Wilson, R. J., R. D. Drobney, and D. L. Hallett. 1992. Survival, dispersal, and site fidelity of wild female ring-necked pheasants following translocation. Journal of Wildlife Management 56:79–85.

CHAPTER 4

GENERAL CONCLUSION

Understanding factors that influence both ring-necked pheasant (*Phasianus colchicus*) occurrence and abundance is essential to developing effective pheasant management strategies. In Chapter 2, I identified the vegetation and anthropogenic features associated with spring habitat use by pheasants using resource selection functions. Pheasant occurrence was positively associated with the amount of forage land, linear density of watercourses, and density of vegetation patches. I also identified the composition of bird communities that might benefit from pheasant habitat enhancements. Both the agricultural and wetland bird communities had positive associations with pheasants, however only the bird communities associated with agricultural development were significant.

In Chapter 3, I investigated the vegetation and anthropogenic features that influenced the abundance of pheasants using zero-inflated negative binomial models. Pheasant abundance as reflected by crow counts was positively associated with distance to the nearest pheasant release site. Pheasant occurrence and abundance were positively related, however different processes appeared to be responsible for each of them.

Vegetation features were the main characteristics driving pheasant spring habitat use. Forage lands, such as alfalfa fields, provide pheasants with a source of food and cover for roosting, nesting, and predator protection (Wagner 1965). Cattails and other tall vegetation that often surround watercourses provide protective and thermal cover for pheasants, especially in winter (Robertson et al. 1993b, Gabbert et al. 1999). Being an edge species, pheasants are primarily associated with the perimeter of a habitat patch and generally require simultaneous availability of more than one type of habitat (Leopold 1933). Greater densities of vegetation patches provide pheasants with an interspersion of food, cover, and display habitats (Yahner 1988). Knowledge of pheasant habitat selection is necessary to develop effective habitat management plans for pheasants in Alberta.

Using the Spatial Analyst (ESRI 2005) function in ArcGIS, the top RSF model was extrapolated across the entire study area to generate a habitat-use map for pheasants (Fig. 2.4). This map indicated that the current Eastern Irrigation District survey routes generally overlapped with areas of high probability of pheasant occurrence (Fig. 2.5). I recommend that these routes continue to be surveyed to monitor pheasant population trends within the Eastern Irrigation District.

In the Eastern Irrigation District, pheasant occurrence was associated with increased species richness. However, only the agricultural bird community exhibited a significant positive association with pheasants. So even though pheasants might function as indicators of avian species richness, the species associated with pheasants are largely those associated with the highly altered agricultural landscape, and not of the native prairie grassland. Pheasants can be used to rally community support for agricultural habitat enhancement projects. Agricultural practices often result in a loss of biodiversity, therefore it is important to develop plans that minimize its impact and retain as much biodiversity as possible. Enhancing agricultural habitats may begin with changing land-use practices such as draining wetlands and removing inconvenient vegetation patches. Other studies have found that some passerine populations have benefitted from game habitat management programs (Stoate 2002, Sage et al. 2005). Habitat improvements to this highly modified landscape are needed to promote biodiversity and maintain a sustainable agricultural environment.

I assessed the vegetation and anthropogenic features that were important to describing pheasant abundance using zero-inflated negative binomial models. Other pheasant studies have found that pheasant abundance was related to habitat features (Jarvis and Simpson 1978, Robertson et al. 1993a, Robertson et al. 1993b, Robertson 1996). However in my study area, abundance of pheasants was positively associated with distance to the nearest pheasant release site. Two hypotheses were proposed to explain lower pheasant abundance near release sites. First, extreme hunting pressure at release sites might result in both released and wild stocks being depleted and thus, reducing pheasant abundance near release sites. Second, released birds might displace wild birds from release site areas and since released birds have lower (overwinter) survival than wild birds (Jarvis and Engbring 1976, Krauss 1987, Brittas et al. 1992, Diefenbach et al. 2000), fewer pheasants would be counted near release sites. Further research is needed to more closely address the impact of releasing pheasants on the wild pheasant population within the Eastern Irrigation District.

Knowledge of vegetation and anthropogenic features that influence pheasant distribution and abundance can assist land managers in making informed decisions regarding pheasant management in southeastern Alberta. While managing for pheasants may be controversial, active management of agricultural habitats is required to maintain and restore healthy and productive habitats within this highly modified landscape. Because pheasants are a popular game species and are so closely tied to the agricultural landscape, communities may actively support agricultural-habitat enhancement projects that are designed to benefit pheasants. Management of agricultural lands should focus on creating a sustainable agricultural environment that includes enhancement of habitats and biodiversity.

1. LITERATURE CITED

Brittas, R., V. Marcström, R. E. Kenward, and M. Karlbom. 1992. Survival and breeding success of reared and wild ring-necked pheasants in Sweden. Journal of Wildlife Management 56:368–376.

Diefenbach, D. R., C. F. Riegner, and T. S. Hardisky. 2000. Harvest and reporting rates of game-farm ring-necked pheasants. Wildlife Society Bulletin 28:1050–1059.

ESRI. 2005. ArcGIS version 9.1. Environmental Systems Research Institute, Redlands, California, USA.

Gabbert, A. E., A. P. Leif, J. R. Purvis, and L. D. Flake. 1999. Survival and habitat use by ring-necked pheasants during two disparate winters in South Dakota. Journal of Wildlife Management 63:711–722.

Jarvis, R. L., and J. Engbring. 1976. Survival and reproduction of wild game-farm pheasants in Western Oregon. Northwest Science 50:222–230.

Jarvis, R. L., and S. G. Simpson. 1978. Habitat, survival, and abundance of pheasants in Western Oregon, 1947–1975. Journal of Wildlife Management 42:866–874.

Krauss, G. D., H. B. Graves, and S. M. Zervanos. 1987. Survival of wild and game-farm cock pheasants released in Pennsylvania. Journal of Wildlife Management 51:555–559.

Leopold, A. 1933. Game management. Charles Scribner, New York, USA.

Robertson, P. A. 1996. Does nesting cover limit abundance of ring-necked pheasant in North America? Wildlife Society Bulletin 24:98–106.

Robertson, P. A., M. I. A. Woodburn, and D. A. Hill. 1993a. Factors affecting winter pheasant density in British woodlands. Journal of Applied Ecology 30:459–464.

Robertson, P. A., M. I. A. Woodburn, W. Neutel, and C. E. Bealey. 1993b. Effects of land use on breeding pheasant density. Journal of Applied Ecology 30:465–477.

Sage, R. B., D. M. B. Parish, M. I. A. Woodburn, and P. G. L. Thompson. 2005. Songbirds using crops planted on farmland as cover for game birds. European Journal of Wildlife Research 51:248–253.

Stoate, C. 2002. Multifunctional use of a natural resource on farmland: wildlife pheasant (*Phasianus colchicus*) management and the conservation of farmland passerines. Biodiversity and Conservation 11:561–573.

Wagner, F. H. 1965. Population ecology and management of Wisconsin pheasants.

Wisconsin Conservation Department Technical Bulletin 34:162–168.

Yahner, R. H. 1988. Changes in wildlife communities near edges. Conservation Biology 2:333–339.