Journal of Environmental Informatics 18(1) 12-21 (2011)

Journal of Environmental Informatics

www.iseis.org/jei

Identification of Bird Collision Hotspots along Transmission Power Lines in Alberta: An Expert-Based Geographic Information System (GIS) Approach

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Received 15 September 2010; revised 16 May 2011; accepted 1 June 2011; published online 12 September 2011

ABSTRACT. Bird collisions with electrical transmission lines are a cause of avian mortality. The exact magnitude of the problem is not known because most avian mortality goes undetected; however, existing mortality estimates make this phenomenon a significant ecological, social and economic concern. Electric utility companies operate thousands of kilometres of transmission line, making it difficult and costly to identify problem sites and prioritize areas for mitigation. Existing research suggests that mortality is not evenly distributed, but spatially clustered in areas with particular combinations of environmental and physical attributes. We used a combination of a geographic information system (GIS) and multiple criteria evaluation (MCE) to predict collision risk hotspots at a landscape scale. Model predictions were validated through preliminary field sampling, which yielded strong evidence that this approach can successfully predict high-risk collision zones. Our spatial approach was a novel application of risk theory within GIS, was transparent, can be easily replicated, and is transferable to other areas with similar problems.

Keywords: Analytical Hierarchical Process (AHP), bird, collision, Multiple Criteria Evaluation (MCE), Geographic Information System (GIS), power lines, risk, waterfowl

1. Introduction

Electrical transmission (power) lines are spatially extensive systems of linear infrastructure. Power lines, like other anthropogenic features, can have negative environmental effects, including impacts on wildlife (Bevanger, 1998). Birds are particular susceptible to negative outcomes because of the potential for aerial collisions (Rubolini et al., 2005). This problem has been recognized since the late 19th century when Coues (1876) reported the collision of 100 horned larks (*Eremophila alpestris*) with telegraph wires. Despite a growing concern expressed by the electric utilities operators, the public, government regulators and researchers, development of remediation methods has been slow to address the problem. Estimates for the USA suggest the annual avian mortality caused by collisions with power lines ranges from 130 and 174 million birds (Erickson et al., 2001). Accurate rates of avian mortality are lacking because, unlike electrocutions, bird collisions rarely cause damage to power lines or interruptions in power transmission; therefore, most mortality goes undetected (Bevanger, 1994).

The risk of bird mortality from power line collision is a function of interacting factors. Power line characteristics that increase the risk of collision include the diameter, number, and configuration of wires. Overhead shield wires, the uppermost wire on most power lines that protect the system from lightning damage, have been found to greatly increase the risk for bird collisions (Scott et al., 1972; Brown et al., 1987; Faanes, 1987; Savereno et al., 1996). Overhead shield wires are smaller in diameter than the transmission wires and therefore less visible to birds. Observational evidence suggests that birds may change course to avoid the lower phase conductors and then collide with the less visible overhead shield wires (Crowder, 2000).

Collision risk is also influenced by flight and morphological characteristics of the bird species, weather conditions, topographic and habitat features, and the spatial orientation of the power lines relative to these features (Anderson, 1978; Beaulaurier et al., 1982). Bird species with high wing loading (weight/wing area) and high aspect ratio (wingspan/wing area) have a greater susceptibility to collision with power lines (Bevanger, 1998; Janss, 2000; Rubolini et al., 2005). These birds have relatively heavy bodies and small wings, fly at high speeds and have limited ability for rapid reaction to obstacles (e.g., waterfowl - swans, geese, and ducks). Another group of birds that is at highest risk for collisions due to morphology includes those species with large broad wings (low aspect ratio), relatively large body size (moderate wing loading) and long necks (e.g., cranes and herons; Janss, 2000). The collision risk for these birds is exacerbated by their flight characteristics, such as flocking activity or low altitude movement

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ISSN: 1726-2135 print/1684-8799 online

patterns between wetlands and feeding areas (Faanes, 1987; Crowder, 2000). In addition to morphology, visibility from low light or inclement weather can impair the ability of birds to detect the presence of power lines in time to take adequate evasive movement (Thompson, 1978; Meyer and Lee, 1979; APLIC, 1994).

We focused our analysis on waterfowl because this group of birds is reported to have a high risk of collision with power lines and waterfowl are of significant social, ecological and economic value within and beyond the study area. Environmental characteristics that attract waterfowl can influence bird collisions with power lines. For instance, many permanent water bodies provide critical staging, breeding and feeding areas; if power lines are situated near these habitat features there is an increased risk of mortality (APLIC, 1994). Power lines that are near sites with significant topographic relief (e.g., steep river valleys, ridgelines) that function as daily movement or seasonal migration flight corridors can also increase the risk of collision (Bevanger, 1994).

Electric power utility companies are compelled to address the issue of bird mortality for ecological, legislative, social-political, and economic reasons. The obvious ecological reasons for mitigation include reducing mortality to birds. Endangered or rare species are of particular ecological concern because the loss of a small number of individuals may have detrimental effects on a population. Many species, especially those at risk of extinction, are protected by law. In fact, it was the collision of endangered Whooping Cranes (*Grus americana*) with power lines in Colorado that elevated the issue of avian-power line collision to international attention in the 1980s (Carlton and Harness, 2001). Avian mortality via power line collision could result in a violation of one or more wildlife protection laws resulting in significant financial costs to a utility operator. In addition to minimizing the costs associated with fines or persecution, utility operators and regulators may be interested in avoiding the potentially negative consequences of citizens witnessing bird collisions with power lines, or finding dead birds in the vicinity of power lines. It is disturbing for people to witness waterfowl-power line collisions. Social-political consequences are more likely where high collision sites are also within high public use areas; in Alberta, it is the public and news media that have raised concerns over high bird collision sites. The loss of individual birds from populations of common waterfowl species may not be of biological significance, but it could create a strong negative response from members of the public who witness or find evidence of the mortality.

Methods to eliminate or mitigate avian mortality from power line collisions are needed and to date include: relocating power lines away from hazard areas, modifying habitat to lower attractiveness to birds, burying power lines, removing overhead shield wires, and modifying or marking lines to increase visibility (APLIC, 1994, 2006; Alonso et al., 1994; Bridges and Anderson, 2002; Crowder and Rhodes, 2002; Carlton and Harness, 2001; Janss and Ferrer, 1998). However, to implement these methods along thousands of kilometres of power lines represents significant time, personnel and financial costs. These costs are a barrier to effectively mitigating the problem of bird collisions with power lines.

Cost-effective techniques are needed to help identify the portions of power lines that pose the greatest collision risk to birds in order to prioritize the deployment of mitigation measures (APLIC, 2006). The spatial nature of bird collision sites with power lines, combined with the availability of relatively low cost environmental and utility infrastructure spatial data make analysis in a GIS a suitable approach to address the problem. However, we found no evidence that GIS had been used to predict collision risk relative to power lines orientation.

We addressed this deficiency using a novel application of decision support methods in a GIS. Our primary objective was to provide a map depicting relative risk of bird collisions with power lines, and to outline a repeatable decision support process that is relatively low cost, can be efficiently deployed, is time sensitive, and explicit. A significant benefit of doing this work within the GIS is that a solution set of high risk collision sites can be provided in map form and can be easily prioritized by respective agencies. This should improve decision capacity and effectiveness of mitigation activities. The model we describe herein was developed from the perspective of a utility operator interested in minimizing the mortality of waterfowl and the potential for negative encounters between the public and birds colliding with power lines.

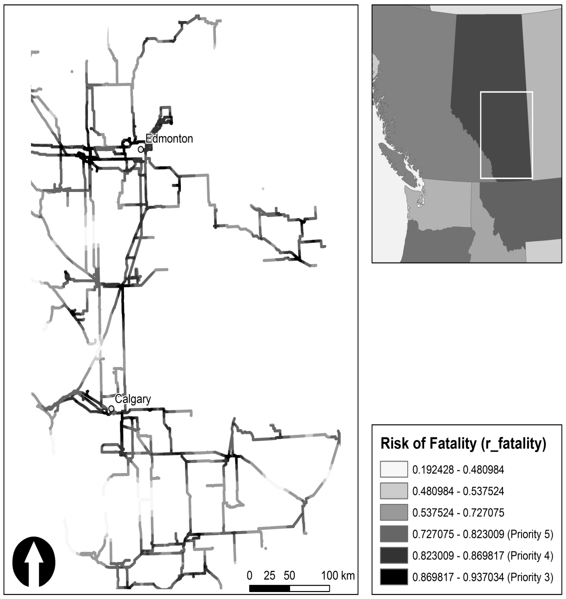
2. Methods

2.1. Approach

We used a decision support system (DSS) approach called Multiple Criteria Evaluation (MCE). MCE is a generic term describing the process of additively combining factors (i.e., measurable criteria) that can be used to make an optimal choice from a set of possible solutions. In a GIS framework, MCE is a specialized form of decision analysis and may be classed as a spatial decision support system (SDSS), where the objective is to find the optimal sites in the landscape for some purpose. In our case, we sought to identify sites of high risk for collisions between waterfowl and power lines. In addition, MCE is also the name of the specific module in GIS (Idrisi version 3.2) that we used to identify and rank various decision criteria. In the present case, our factors were those aspects of the landscape or built environment that could be used to measure habitat quality and collision risk. Our factors included spatial measures such as proximity to water and proximity to power lines.

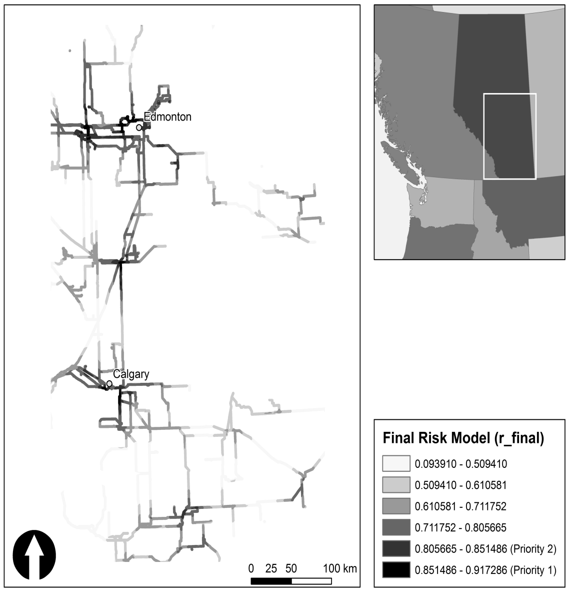
In MCE, it is assumed that factors may be combined additively. In some cases, each factor can contribute equally to the optimal solution, but in most cases, factors have different levels of importance. Thus, we ranked our factors using the Analytical Hierarchical Approach (AHP) developed by Saaty (1980). This is a well accepted approach to conducting paired comparisons of factors and ranking importance, and is embedded within the MCE module in Idrisi 3.2.

To determine collision risk, we first needed to develop a predictive model that showed the range of suitability of habi-



Notes : r_fatality = r_collision × r_habitat

Figure 1. Probability of fatality (r_fatality).



Notes : risk_final = r_fatality × r_social

Figure 2. Final risk model (risk_final).

tat for waterfowl. We did this by identifying critical habitat features (factors) and combining them in the MCE module. Our MCE habitat model was based on the concept that certain habitat attributes can be used to predict species occurrence (Beutel et al., 1999). Models defining the relationship between a species and its environment are called species-environment models, and these have been used previously to model threats to wildlife (e.g., to quantify the amount of habitat that will be lost with a housing development, to quantify the fragmentation of suitable habitat by the development of a new road; Reckhow et al., 1987; Cumming, 2000, Scott et al., 2002).

The use of MCE in developing a species-environment model is classed as a knowledge/expert based approach (Kang and Alexander, 2009). This approach differs from traditional data driven models such as logistic regression, multivariate analysis, among others, and is very useful in situations where one needs to make a rapid assessment with a paucity of data. For instance, if one does not have funds or time to do a comprehensive habitat assessment for waterfowl in an area of interest, then expert understanding of relationships from other areas can be adopted and generalized to the area of interest. Despite the non-data driven approach, MCE habitat models for wild species have been found to have high accuracy when compared to more conventional data-driven techniques (Kang and Alexander, 2009).

As part of our final objective we developed a map that showed risk of waterfowl collision with power lines. We defined risk as a function of the probability × consequence (Kirkland and Thompson, 2002). To accomplish this, we required two MCE models: a bird collision risk model, which reflected the intersection between a range of habitat quality and the presence of power lines (probability); and, a social consequence model, which reflected the possibility that a citizen of Alberta might observe a dead bird and be upset with the utility company (consequence). The merging of MCE, the concept of risk identified by Kirkland and Thompson (2002), and GIS created a novel process that addressed a deficiency in power line environmental impact assessment.

2.2. Study Area

Our study area was located in south and central Alberta, Canada (Figures 1 and 2). The electrical transmission infrastructure is owned and operated by a single company, AltaLink, with nearly 12,000 km of power line servicing over 2.8 million people (AltaLink, 2003). This area is part of the Pacific and central flyways, two major linkage zones for migratory waterfowl. The prairie and parkland landscape is characterrized by a large number of shallow, distributed wetlands (potholes) formed by the retreat of the last continental glaciers. It is part of the larger prairie pothole region, an 800,000 km^2 area of west-central North America that provides highly productive breeding habitat for half of the continent's waterfowl (Austin et al., 2001).

2.3. Model Development

2.3.1. Identification of Factors, Constraints and their GIS Equivalents

The objective of decision analysis is to select the most suitable candidate of a set of alternative choices. Following from above, our objective required that we identify factors that influence two different conditions: collision risk (i.e., habitat suitability and power line presence) and social consequence. Our factors for each objective are detailed below.

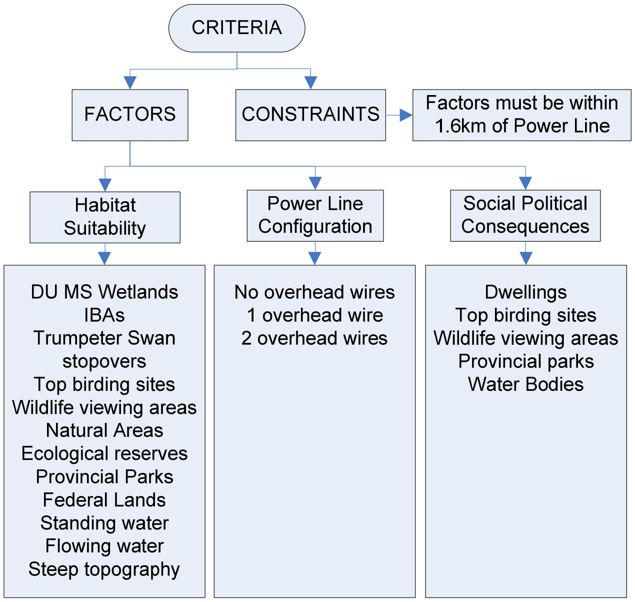


Figure 3. Analytical hierarchy technique applied to examine avian risk of collision with power lines.

2.3.2. Bird Habitat Factors and Collision Risk

Habitat quality was defined using environmental predictors for waterfowl, which were identified through a review of literature and refined to match available spatial data that could be used in a GIS. The five categories of habitat quality for waterfowl included maps of the following: 1) published/known productive birds areas, 2) other potential high habitat use areas, 3) standing water, 4) moving water and 5) steep topography (Table 1).

The GIS layers that were used to represent habitat factors were as follows: Ducks Unlimited moulting and staging wetlands (Ducks Unlimited, 2006), Important Bird Areas (IBAs) (BirdLife International, 2004), trumpeter swan stopover wetlands (LaMontagne et al., 2003; Fontana, 2006), top birding sites (Fisher and Acorn, 1998), wildlife viewing areas (Alberta Forestry, Lands and Wildlife, 1990), natural areas (AltaLIS, 2006), environmental reserves (AltaLIS, 2006), provincial parks (AltaLIS, 2006), and federal lands (AltaLIS, 2006). Standing and moving water features (wetlands, lakes, reservoirs, streams, rivers and river valleys) were acquired from 1:20,000 Alberta Base Features data (AltaLIS, 2006). A digital elevation model (DEM) was constructed from the Alberta Base DEM (AltaLIS, 2000) raster data (tiled by NTS Map Sheet) for the entire study area. Terrain was considered steep if it exceeded 10 degrees and was extracted from the DEM according to this criterion.

Data for the above factors were extracted for the area to within 1600 m of existing power line infrastructure. Published research indicated that bird collisions are not expected beyond 1600 m from a power line (Brown et al., 1987) and we applied this value as a constraint in our model. Recorded data were discreet (i.e. binary – 1 = presence, 0 or No Data = absence), and were used as inputs in the creation of distance grids or spatial proximity indices. The "distance" module in ESRI ArcGIS v.9.0 Spatial Analyst Extension was applied to calculate Euclidean (straight line) distance to the nearest feature of concern. Separate distance grids were calculated for each of the five factors and used as inputs in the habitat model. The resolution of these raster layers was 50 m; this cell size allowed for efficient computation and is also suitable for informing management decisions.

Risk of collision exists when a power line is too close to suitable waterfowl habitat. The presence of an overhead shield wire (1 or 2 wires) was included as the singular factor that predicts the likelihood of collision. Other power line features known to increase bird collision risk (e.g., conductor configuration) were not used because the spatial data were not available.

This risk factor was represented with the GIS layer showing existing power line infrastructure (AltaLink, 2006). Separate spatial proximity indices were created for single and double overhead shield wires, again using the "distance" module of ArcGIS Spatial Analyst and calculating the Euclidean distance to the nearest feature of either type.

2.3.3. Social Consequence Factors

Social consequence is defined here as the likelihood that a member of the public will view a collision or a dead bird. While some factors used here are replicates of those used in the habitat model, they are used differently to measure human habitat suitability for witnessing collisions or encountering dead birds. Essentially, the MCE consequence model is designed to create a set of 'optimal opportunities for viewing dead birds'.

The social consequence factors included: 1) areas with a population density of 15 dwellings/ha or greater, 2) published popular bird watching locations (Fisher and Acorn, 1998), 3) published wildlife viewing areas (Alberta Forestry, Lands and Wildlife, 1990), 4) provincial parks (AltaLIS, 2006), and 5) permanent standing water bodies (AltaLIS, 2006) the public may use recreationally. Presence of these features within 1600 m of power lines was used as input for the creation of 5 spatial proximity indices, using the same method described above.

2.4. Ranking Factors using Analytical Hierarchical Procedure (AHP)

The relative importance of each of the factors was determined through a review of waterfowl habitat use literature and consultation with regional waterfowl biologists.

The importance of each factor relative to every other factor was assigned by combining habitat relationships specified in the literature with expert opinion, and using Saaty's (1980) AHP (within Idrisi 3.2). AHP uses a paired comparison approach and a 9-point rating scale. The AHP used in the MCE is illustrated in Figure 3.

The MCE module in Idrisi 3.2 has a built in function (i.e., WEIGHT module) that allows the user to calculate the relati-

Table 1. Collision Factors Characterized According to Risk

Category	Description of Category	Habitat type and source of data	Importance in Relation to Collision Potential
Productive Waterfowl Areas (prod_ba)	Locations where the largest concentration of waterfowl and water-birds are expected to be found in the study area	1. Identified molting and staging wetlands (Ducks Unlimited Canada, 2007) 2. Important Bird Areas (BirdLife International, 2004) 3. Trumpeter Swan stopover wetlands (Fontana, 2006; LaMontagne et al., 2003) 4. Top Birding Sites (Fisher and Acorn, 1998) 5. Wildlife Viewing Areas (Alberta Forestry, Lands and Wildlife, 1990)	Very Important
High Habitat Use Areas (high_hab)	Areas of relatively intact and productive habitat protected by some form of legislation	1. Natural Areas (AltaLIS, 2006) 2. Environmental Reserves (AltaLIS, 2006) 3. Provincial Parks (AltaLIS, 2006) 4. Federal Lands (AltaLIS, 2006)	Important
Standing Water (h2o_std)	These are areas where waterfowl and water birds would be expected to be found but are not actually designated as productive bird areas	Source: Alberta 1:20,000 BaseFeatures vector data (AltaLIS, 2006). Includes standing water features (wetlands, lakes, reservoirs).	Somewhat important
Moving Water (h2o_mov)	These are areas where waterfowl and water birds may be found but less likely than standing water areas and productive bird areas	Source: Alberta 1:20,000 BaseFeatures vector data (AltaLIS, 2006). Includes all flowing water.	Less important
Topography (steeps)	Areas with a slope of >10^{o} were used to indicate potential aerial movement corridors	Source: Alberta Base Terrain 1:20,000 DEM (AltaLIS, 1998-2000). Includes river valleys and other areas of steep linear depressions.	Less important
Overhead Shield Wire (OHSW)	The majority of collisions have been found to occur with OHSW	Source: AltaLink transmission lines data (AltaLink, 2006). 1. 0 OHSW 2. 1 OHSW 3. 2 OHSW	Important
Presence of People (hd_popn)	When witnessed by the public, bird collision can have a social political impact.	Source: Statistics Canada (2002). Includes areas with more than 15 dwellings per hectare.	Important

ve weight of each factor from the AHP tables. Here, the factor weight refers to the relative contribution the factor may have to finding the optimal solution. For instance, the presence of water may be more critical to habitat for waterfowl than the proximity to running water. Typically, AHP provides an organized structure for group discussions about factors, and helps decision making groups identify and come to consensus about the relative importance of factors (Eastman, 1999). However, it can provide a structure by which to incorporate relative importance of factors as identified through the literature. We used information from published literature combined with professional opinion to rank the paired factors.

2.5. Spatial Model Development

2.5.1. Standardizing Factors in GIS

Each GIS factor had to be rescaled in order to combine the GIS layers; the factor weights (factor loading scores) are designed such that the total score for any site equals one (1.0) and each input factor can only contribute a portion to that final value, and the total contribution to the each site cannot add up to more than 1.0. In Idrisi 3.2, a module called FUZZY was used to rescale each GIS factor. The rescaling has the effect of creating equivalent ranges of values (from 0.0 ~ 1.0) for every factor used in the MCE regardless of its original range of values.

2.5.2. Weighting Factors in GIS

The WEIGHT module from the Analysis/Decision Support menu in Idrisi 3.2 was used to derive factor loading scores that are used in the MCE module to ascribe these weights to the GIS factors. The MCE assigns relative importance (factor loading scores) to each GIS layer using a weighted linear combination approach (Eastman, 1999). Factor loading scores may be loosely equated with a variable's coefficient in a regression analysis. Factor loading scores are multiplied by the standardized GIS layers (see above, GIS layers standardized using the FUZZY approach), and then each layer is added together. The final scores for any point on the output vary from 0.0 ~ 1.0. We repeated this MCE linear combination process twice: once for the bird habitat/collision risk model and once for the social-political consequence model.

2.5.3. Final GIS Risk Model

We defined risk as a function of probability × consequence, based on Kirkland and Thompson (2002), where probability = (habitat quality) × (likelihood for collision) and consequence = (social consequence). Our final GIS model was developed by multiplying together the respective GIS predictive models that were derived using MCE and factor loading scores, in accordance with the calculations specified above.

2.5.4. Priority Assessment

To rank areas according to risk, we viewed the final risk map values as a histogram, using Layer Properties Classification in ArcGIS 9.0 (ESRI, 2007). Natural ranges of values were aggregated using the ArcGIS Natural Breaks module (ESRI, 2007). These natural breaks were then modified into categories of final risk (probability × consequence). Five categories considered highest risk were identified based on the natural breaks.

The sites considered highest risk have a high probability of collision occurrence (i.e., there is a power transmission line in high quality waterfowl habitat) as well as a high risk for social-political consequences to occur (i.e., near an area frequented by people). These sites are indicated in the Final Risk Model (r_final) as Priority 1 and Priority 2 sites (Figure 2); these are sites where the highest management value for mitigation would be achieved. Priority 3, 4, and 5 sites scored highest in the Probability for Fatality model (r_fatality) (Figure 1) but have a lower risk for social-political consequences. We decided to include high risk sites identified in the probability surface model in our final priority list, even if they did not score high for social consequence because they represent the actuarial aspects of the problem. As responsible corporate citizens, electric utility operators should reduce bird collisions at high kill sites even if the social political consequence is lower. All other sites were not included as priorities for mitigation.

2.6. Model Validation

We conducted a pilot study, using systematic sampling for dead birds along existing power lines. Searches for dead birds were conducted according to methods described by the Avian Power Line Interaction Committee (APLIC, 1994) in June of 2006 and 2007 during spring migration. Evidence of collision included both carcasses and feather spots (Beaulaurier, 1981). Feather spots are a tight cluster of feathers that are left behind when a bird is scavenged (APLIC, 1994). Past research (see Anderson, 1978; Brown et al., 1987; Faanes, 1987) has indicated that dead bird searches may only account for 26% of actual strikes. We collected the following data when dead birds or feather spots were found: location of carcass (GPS), species, sex, physical condition (e.g., broken bones, blood, decomposition, feeding damage by scavengers).

Searches covered the entire transmission right-of-way (ROW), in a zigzag fashion to ensure systematic coverage (APLIC, 1994). Search widths were chosen according to James and Haak (1979), Raevel and Tombal (1991), and Hartman et al. (1992).

500 kV line: 50 m from the outer conductor on either side

230 kV line: 45 m from the outer conductor on either side

115 kV line: 20 m from the outer conductor on either side.

Dead bird searches were conducted along 500 m transects of ROW at twenty sites over two field seasons. Eighteen of these sites were within 1600 m of standing water and two sites were at locations where the power line crossed a river valley (slope > 10 degrees). We attempted to establish control transects at all sample locations, but, due to issues of private land access, only seven of the twenty sites had matching controls. Control searches were conducted at the same sites as the ROW searches but away from the overhead power transmitssion line. These searches were used to verify that dead birds found under power lines are the result of a power line collision and not some other source.

Sites were categorized according to how close a power line came to a water feature: within 60 m, 60 ~ 500 m, 500 ~ 1600 m, and crossing perpendicular to a river valley with a steep slope. This was used to simultaneously validate the assumption that the distance of a power line to a high risk feature is critical in determining the level of risk. A chi-square test was used to test for significant differences between site categories (Fowler and Cohen, 1995).

While our pilot search was systematic, it was biased for limited time, access to private lands, financial resources and dead bird visibility. We note that this was a pilot validation and was developed to do an initial appraisal of performance and to identify an appropriate method, and challenges to executing such field work. All sites had short or mixed grass and were on dry ground to facilitate search and recovery. Sites also had to be accessible by motor vehicle and permission had to be obtained from landowners.

3. Results

3.1. Multiple Criteria Evaluation

Environmental, power line, and social factors were identified through a literature review and used to develop bird habitat, bird mortality risk, and social consequence models. PCA matrices were created for habitat suitability, power line configuration, and social political consequence using Saaty’s 9-point rating scale (Tables 2 to 4). All ratios were calculated

Table 2. Pairwise Comparison Matrix for Suitable Habitat Probability Factors

	Proximity to Productive Birds Area	Proximity to High Habitat Use Area	Proximity to Standing Water	Proximity to stream or river	Proximity to Topography
Proximity to Productive Bird Area	1				
Proximity to High Habitat Use Area	1/3	1			
Proximity to Standing Water	1/6	1/5	1		
Proximity to stream or river	1/7	1/6	1/4	1	
Proximity to Topography	1/7	1/6	1/4	1	1
Weight Module Results	0.5032	0.2930	0.1146	0.0446	0.0446

to be below 0.10, indicating that the logic used to determine factor weights was consistent.

3.2. Final Model: Risk

The following formulae were used in ArcGIS Raster Calculator to create the final risk model (where Risk = Probability × Consequence). Here, probability is determined by multiplying the habitat potential layer by the proximity to power line layer, and consequence is determined calibrating the habitat model with proximity to urban centre. The equations used are described below (see Table 1 for abbreviations):

$$\text{Risk} = \text{Probability} \times \text{Consequence}$$

where, Probability = (habitat suitability) (likelihood for collision) = (1 - [(0.2930) × d2_high_hab + (0.5032) × d2_prod_ba + (0.1146) × d2_h2o_std + (0.0446) × d2_h2o_mov + (0.0446) × d2_steeps]) (1 - [(0.0614) × d2_ohsw_0 + (0.5659) × d2_ohsw _1 + (0.3727) × d2_ohsw_2]). Consequence = (social implications) = 1 - [(0.4642) × d2_hd_popn + (0.2544) × d2_ high_ hab + (0.1839) × d2_prod_ba + (0.0975) × d2_h2o _std].

3.3. Ground Truthing

During the forty-seven site searches 32 ducks, 2 pelicans, 11 medium to large water birds, 43 gulls, 3 passerines, and 14 unknown birds, all believed to be power line collision victims, were found. These birds were found in various stages of decomposition. Typical findings include feather patches, wings, bones and full carcasses.

Dead birds were found at nine out of fourteen sites where collisions were expected and no dead birds were found in two out of five areas where no dead birds were expected. No dead birds were found at any of the seven control sites. Dead birds found at each site were standardized to dead birds per 100 m. Two-thirds of all dead birds found were in areas where the power line was situated within 60 m of a water body. These results show that there is a significant difference ($p = 0.0012$, df = 3) between levels of risk for the different categories of sites.

Table 3. Pairwise Comparison Matrix for Power Line Probability Factors

	0 OHSW*	1 OHSW	2 OHSW
0 OHSW	1		
1 OHSW	7	1	
2 OHSW	8	1/7	1
Weight Module Results	0.0614	0.5659	0.3727

* OHSW = number of overhead shield wires.

4. Discussion

The model we developed helps to predict areas of higher risk compared to all other areas across the landscape. There likely will be high-risk sites that are not identified at this level of analysis and management must be flexible enough to re-prioritize sites when such features are discovered, either through ground truthing studies or reported by from an external source."Habitat models are a means of quantitatively assembling best knowledge of animal-habitat relationships to make informed decisions possible, rather than expecting the models to be perfectly predictive with $p < 0.05$" (Van Horne, 2002).

Sources of error associated with this research include assumptions made in the ground truthing methods and detection bias. To ground truth, all carcasses and feather patches found under a transmission line were assumed to be evidence of collisions (Beaulaurier, 1981) and not from some other source, such as vehicle collisions or natural death. To be confident that a bird's death was from power line collision, a necropsy must be performed. However, this was not possible because in many incidents the carcasses were too decomposed. Furthermore, our carcass search differed somewhat from others. Past studies have focused on specific sites where the researcher spends several days, weeks or months monitoring the same site and conducts regular, daily carcass searches. This allows for fresh carcass collection upon which a necropsy can be performed. In this study it was assumed that past

Table 4. Pairwise Comparison Matrix for Social and Political Consequence Factors

	Proximity to Urban Centre	Proximity to Productive Bird Area	Proximity to High Habitat Use Area	Proximity to Standing Water
Proximity to Urban Centre	1			
Proximity to Productive Bird Areas	1/3	1		
Proximity to High Habitat Use Area	1/2	2	1	
Proximity to Standing Water	1/4	1/3	1/2	1
Weight Module Results	0.4642	0.1839	0.2544	0.0975

research was accurate and that power lines situated in close proximity to productive bird areas and other areas supporting significant waterfowl populations would have collisions. Under this assumption, it would then be logical to assume that dead birds and feather spots were indications of collisions. The result of the control searches, where no power line was present, no dead birds or their parts were found. This supports the assumption that all dead birds under power lines are the result of power line collisions.

During the ground truthing pilot, 43 gulls were discovered. Thirty-five of those gulls were found at the same site, all within 200 m of each other. At this location, an unanticipated industrial feature that greatly increased collision risk for the gulls was discovered; the power line was located in between a private landfill and a wetland. This is an example of how a feature, unrelated to the power line, can create unusually high collision risk. The gulls here were observed in high numbers flying back and forth between the wetland and the landfill. One gull was seen colliding with the shield wire during the survey. This type of scenario cannot be accounted for in the GIS models. If those 35 gulls are removed from the results, then the findings do support past research by Beaulaurier (1981), Faanes (1987), Bevanger (1998), Bevanger and Brøseth (2004) where it was found that gulls collide with power lines much less frequently than do waterfowl and other medium to large water birds.

Past studies conducted on power line systems have found that a very small percentage of line accounts for a very large percentage of the problem. In our study area, only 2.2% of transmission lines were classified as “high-risk”. These high-risk segments of line should be mitigated to reduce overall avian-collision mortality. Although this 2.2% is by no means all-inclusive (i.e., collisions can occur anywhere there are overhead power lines), it does represent the highest-risk areas on the grid and indicate where the utility operator can achieve the best efficiency for expenditures on mitigation.

Furthermore, by mitigating transmission lines within these high-risk priority areas, the utility operator will be able to show due diligence to stakeholders, including provincial and federal regulators with respect to the Alberta Wildlife Act, Species at Risk Act, and the Migratory Birds Convention Act. Approximately 85% of Alberta’s population resides in southern and central Alberta (AltaLink, 2004), within the Pacific and central migratory flyways and the prairie pothole region. There is approximately 12,000 km of existing transmission line in this area. This research and risk assessment can be used as an assessment tool for prioritizing transmission lines for mitigation as part of an Avian Protection Plan, in identifying study sites for conducting research and testing mitigation devices, and for developing guidelines for new transmission lines.

An Avian Protection Plan (APP) is a management system for electric utilities that is specific to birds, designed to reduce the operational and avian risks that result from avian interactions with electric utility facilities (APLIC and USFWS, 2005). The framework was developed jointly by APLIC and USFWS (2005) and although not a legislated requirement, has been widely adopted by utilities in the USA. To date, only two Canadian utilities have implemented an APP. In order to have the greatest impact on reducing avian mortality, a risk assessment is undertaken as part of the APP process (APLIC and USFWS, 2005). Risk assessment methods have been developed to address avian electrocution, but not for collisions. The likely reason for this is the lack of reporting and general difficulties in identifying collision areas. Because electrocution results in a power outage, it is easier for companies to identify and monitor high-risk electrocution sites.

APLIC currently recommends that a two-year, four-season study be carried out to determine the extent of the collision problem (Bridges and Anderson, 2002). When a great number of sites are suspected of having collision risk, this recommendation becomes unfeasible. When resources are limited, this certainly is not a viable solution. The risk assessment and GIS model presented in this study could be used as a method for carrying out a risk assessment for collisions.

Our objective was to build a GIS model that identified collision hotspots for birds at a large scale, and to provide a repeatable, transparent spatial decision process that can be applied at a large scale for little cost. The sites identified by our landscape scale model successfully identified hotspots, based on searches for dead birds. In addition, we were able to illustrate how this process may be used to quickly ascertain where mitigation efforts might be placed. Under a regime of continued power-line development, increased social pressure for environmental engagement of large corporations, and increased costs of surveying power lines, we believe our model provides a cost-effective structure for use in prioritizing and streamlining mitigation efforts.

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