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Strategies to identify dangerous electricity pylons for birds

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Abstract. Bird electrocution rates in Secanos de Lérida, an important bird area in central Catalonia (northeast Spain), were estimated based on 804 visits to 507 electric pylons between 1995 and 1999. Electrocution caused a minimum of 160 victims on 67 pylons. Victims were corvids (36%), diurnal birds of prey (60%) and owls (4%). Electrocution rates ranged between <0.01 birds · pylon^{-1} · year^{-1}, in the less risky areas, and 0.20 birds · pylon^{-1} · year^{-1}, in the areas with higher risk. The number of electrocution victims per killing pylon ranged from 1 to 12. Casualties occurred in a fairly contagious pattern, since 50% of deaths took place on only 2% of the visited pylons, and 50% of the killing pylons accumulated 80% of the victims. Univariate analysis revealed that the technical design of the pylons was very important in determining the potential danger of electrocution (metal crossbows were found to be the most dangerous design, followed by earthed flat pylons and vaults). Most mortality (97%) could be eliminated if all technically dangerous pylons were modified, but these would entail 67% of the pylons in the study area. Modelling the presence of carcasses under the pylons was used to identify the pylons which concentrate casualties, so that a 'preferred pylon' approach could be used to allocate mitigation resources. A single under-line inspection identified 78% of the pylons causing bird casualties in the area, which were responsible for 91% of the deaths. Information collected during this single inspection was used to build a logistic model which allowed the correct classification of most of the dangerous pylons missed in the first inspection. This approach revealed that geographical location and habitat setting were as important as technical design in determining the actual risk of electrocution. In that way, up to 99% of mortality can be eliminated by modifiying only 23% of the pylons in the area.

Key words: birds of prey, Catalonia, conservation, electrocution, Lérida, logistic model, power lines, Spain

Introduction

Power line electrocution causes the deaths of thousands of birds around the world (Bevanger 1994; Bayle 1999) and, in some areas, it is considered the main reason for the decline of endangered species (Ferrer et al. 1991; Real and Mañosa 1997; Bevanger and Overskaug 1998). The technical and biological aspects leading to electrocution are fairly well understood (Olendorff et al. 1981; Ferrer et al. 1991; Olendorff 1993; Bevanger 1994, 1998; Avian Power Line Interaction Committee 1996; Guzmán and Castaño 1998), so that effective and permanent mitigation techniques adequate to several pylon designs have been devised and tested (Miller et al. 1975; Regidor et al. 1988; Negro et al. 1989; VDEW 1991; Janss and Ferrer 1999a).

Eradication of the electrocution problem on existing power lines can be based on the implementation of such modifications on every dangerous pylon. But some authors have also suggested a ‘preferred pylon’ approach (Williams and Colson 1989), based on the fact that most electrocution casualties concentrate on a small percentage of pylons (Benson 1982; Williams and Colson 1989). This approach allows a faster and much more cost-effective elimination of the problem, but needs the elaboration of tools to identify such pylons (Janss and Ferrer 1999b). Small distances between conductors, or between conductors and earthed devices, as well as the location of the pylon in the terrain – especially in areas or habitats of perching birds of medium to large size – are the crucial factors that make some pylons much more dangerous than others (Olendorff 1993; Bevanger 1994).

The objective of this paper is to identify the best approach to eradicate bird electrocution in an important bird area of northeast Spain. To do so, the pattern of bird electrocution in the area is analysed and several predictive models are constructed, in order to identify high hazard pylons. On the basis of these models, the performance of several strategies for the allocation of the mitigation actions are compared in terms of the cost-effective reduction of casualties.

Study area and methods

The study was conducted in the important bird area ‘Secanos de Lérida’ (Viada 1998) in central Catalonia (northeast Spain) (Figure 1). The area provides refuge to breeding populations of Northern goshawk (*Accipiter gentilis*) and European buzzard (*Buteo buteo*) (Mañosa and Cordero 1992; Mañosa 1994). It is also relevant as a juvenile dispersal area for the Bonelli’s eagles *(Hieraaetus fasciatus*) (Mañosa et al. 1998), which are listed as endangered in Europe (Tucker and Heath 1994). On the basis of different landscape characteristics and the presence of birds of prey (Muntaner et al. 1983; Ferrer et al. 1986; Mañosa et al. 1998), three subareas were identified (Figure 1), whose limits were set following the 10 $\times$ 10 km Universal Transverse Mercator grid. The Llobregós subarea is dominated by cereal crops mixed with oak forest. Seven species of diurnal birds of prey were breeding in the area, including the Golden eagle (*Aquila chrysaetos*) and the Bonelli’s eagle. Wintering red-kites (*Milvus milvus*), and non-breeding Bonelli’s and Golden eagles were also common, as well as breeding Eagle owls (*Bubo bubo*), ravens (*Corvus corax*), and Carrion crows (*Corvus corone*). The Sió subarea is a flat region dominated by cereal crops and the absence of woodland. Breeding Golden or Bonelli’s eagles were absent, but non-breeding individuals of boths species were common during winter. Up to 3 species of diurnal birds of prey and the Carrion crow use the area to breed. The Ondara subarea is a rugged region, dominated by cereal crops and scattered pine forest. Only 3 species of diurnal birds of prey use the area to breed, and the area is seldom visited by Golden or Bonelli's eagles. Based on these differences, the Llobregós subarea was given a high 'bird of prey' score, the Sió subarea a moderate score, and the Ondara area a low score.

Between December 1995 and December 1999, we visited 507 pylons on 1–7 occasions each, totalling 804 pylon visits. The number of visits per pylon was accidental, although more visits were conducted to pylons where victims were

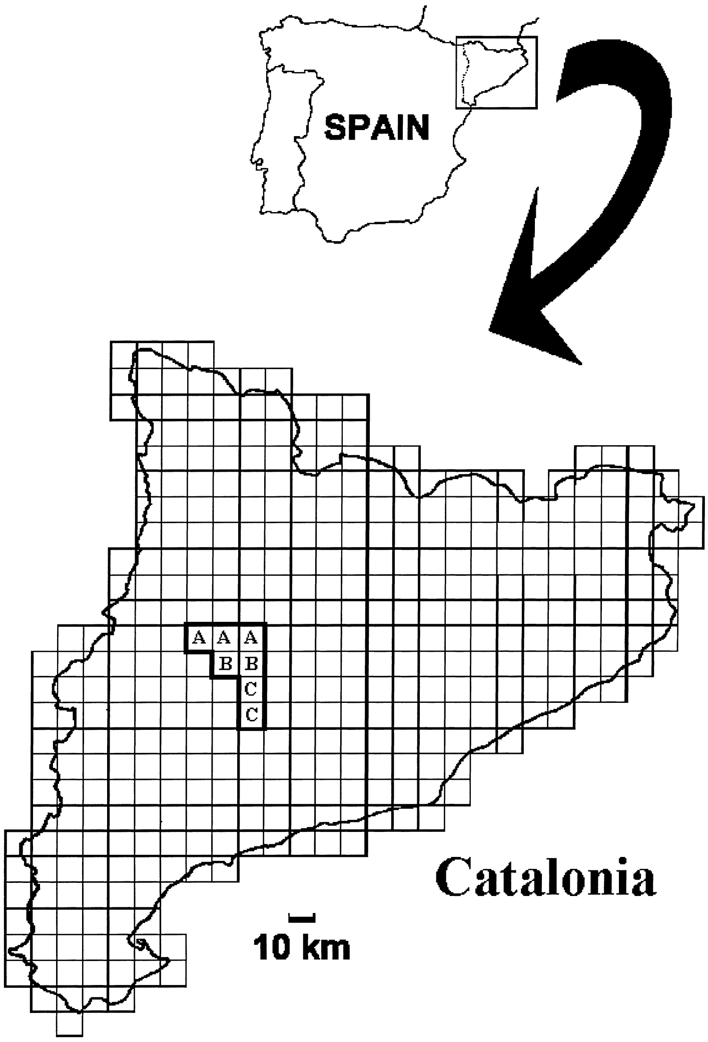

Figure 1. Study area and subareas considered within. A: Llobregós subarea, B: Sió subarea, C: Ondara subarea.

found. On each visit, any bird carcass found below a pylon was identified, checked for signs of electrocution and removed to prevent double counting in subsequent visits. Time from death was estimated according to the condition of the corpses or remains, which were classed as being more than one year old (dry and dispersed bones) or less than one year old (freshly dead, active putrefaction, mummified corpses, well preserved feathers). This method tends to overestimate time from death, because the decay process and loss rate of carcasses can be very high (Ferrer et al. 1991), but the method allowed us to obtain a rough estimate of the minimum annual killing rate.

Several pylon characteristics, which could potentially be related to the occurrence of electrocutions, were recorded during the visits (Table 1). The ‘bird of prey score’ of the subarea (Figure 1) where a pylon was situated (AREA) may be relevant in determining the occurrences of electrocution, as pylons in areas with higher bird of prey populations may have a greater probability of producing accidents (Janss and Ferrer 1999b). The dominant habitat 25 m around the pylon (HABI) may be related to the use of the pylon as a hunting perch, both because birds of prey are attracted to habitats

Table 1. Technical and habitat variables considered in describing the pylons.

Variable	Description
FUNC (pylon function)	
Holder	Pylons that hold or strain the conductors
Derivation	Pylons where the line splits into several branches
Dispositive	Pylons with transformers, fuses, or circuit breakers
MATE (pylon conductivity)	
Unearthed	Wood or concrete; not earthed; non-conductive
Earthed	Wood or concrete; earthed; conductive
Metal	Build on metal; conductive
MODEL (Figure 2)	
Vertically arranged	see Figure 2.1. Metal; earthed
Cross	see Figure 2.2. Wood or concrete; unearthed
Vault	see Figure 2.3. Metal or concrete; earthed
Flat	see Figure 2.4. Metal or concrete; earthed
Crossbow	see Figure 2.5. Metal; earthed
INSU (insulator type)	
Suspended	Suspended insulators or jumpers under crossarms
Exposed	Pin-type insulators or jumpers over the crossarms
HABI (habitat 25 m around)	
Urban	Buildings, paved roads
Crop	Cereal or tree crops
Natural dry pasture	Natural vegetation cover <1 m high
Open woodland	Open oak woodland
TOPO (topographic placement)	
Non-outstanding	Side-hill, flat area, or valley bottom
Outstanding	Top of a peak, ridge, or saddle

where prey are abundant or because they avoid disturbed habitats. In general, pylons in urban areas are avoided and those in shrubland are favoured, while croplands show intermediate preference values (Guzmán and Castaño 1998; Janss and Ferrer 1999b). For a bird of prey hunting from a perch, the immediate vegetation cover surrounding a pylon may be the most relevant in determining visibility and accessibility to prey, so that a radius of 25 m was selected. The topographic placement of the pylons (TOPO) may also be related to the probability of a pylon being selected as a perch. Pylons providing considerable elevation above the surrounding terrain may provide birds with a wide range of vision and easy take-off and landing (Olendorf 1993), so that pylons on the top of peaks, ridges, or saddles may be more dangerous than those on side-hills, flat areas or valley bottoms (Benson 1982). Bird electrocution occurs when a bird makes simultaneous contact with two conductors or a conductor and a grounded device (Bevanger 1994). Besides bird size (Bevanger 1998), several technical characteristics of the pylons facilitate the occurrence of these events. Pylon function (FUNC) is related to the number of conductive wires on the top of the tower. More conductors and jumpers on top of the pylon may increase the probability of electrocution. The pylon material (MATE) is related to the conductive characteristics of the pylon. Earthed pylons or those built of conductive material may be more dangerous than unearthed pylons built of non-conductive materials (Olendorff et al. 1981). The configuration of the top of the pylon (MODEL, Figure 2) is related to the number and characteristics of the perching points. Models containing more potential perching points close to conductive elements may be more dangerous. Insulator type (INSU) is related to the presence of conductive elements over the crossarms, which may increase the potential for electrocution (Ferrer et al. 1991). Finally, the presence of electrocuted birds near neighbouring pylons (NEIG: yes; no) may be indicative of the use by birds of prey of a given area, in the absence of other sources of information. Technical terms follow Janss and Ferrer (1999a) (Figure 3).

Univariate statistics were used to analyse the importance of the above mentioned factors in determining the risk of electrocution. But the relative contribution of every factor was studied by means of a multivariate approach to eliminate the biases involved in the sampling procedure. I built logistic regression models relating the presence or absence of carcasses on a pylon with several combinations of six of the above mentioned variables (FUNC, MODEL, HABI, TOPO, NEIG, AREA). Logistic regression models are similar to multiple regression models but are adapted to cases in which the dependent variable (the variable we wish to predict) is dichotomous and can take the value 0 (event not occurring) or 1 (event occurring). Logistic regression is used to predict the probability of occurrence of a given event in relation to the values of a certain number of predictive variables. In our case, the logistic regression model can be written as: Probability (presence of a carcass) = $1/(1 + e^{-z})$, where $z = (B_0 + B_1X_1 + B_2X_2 + \cdots + B_iX_i)$, B_i are the coefficients for the i variables included in the model, and B_0 is a constant. Since all our independent variables were categorical, $a-1$ dummy variables were created for each original variable, where a is

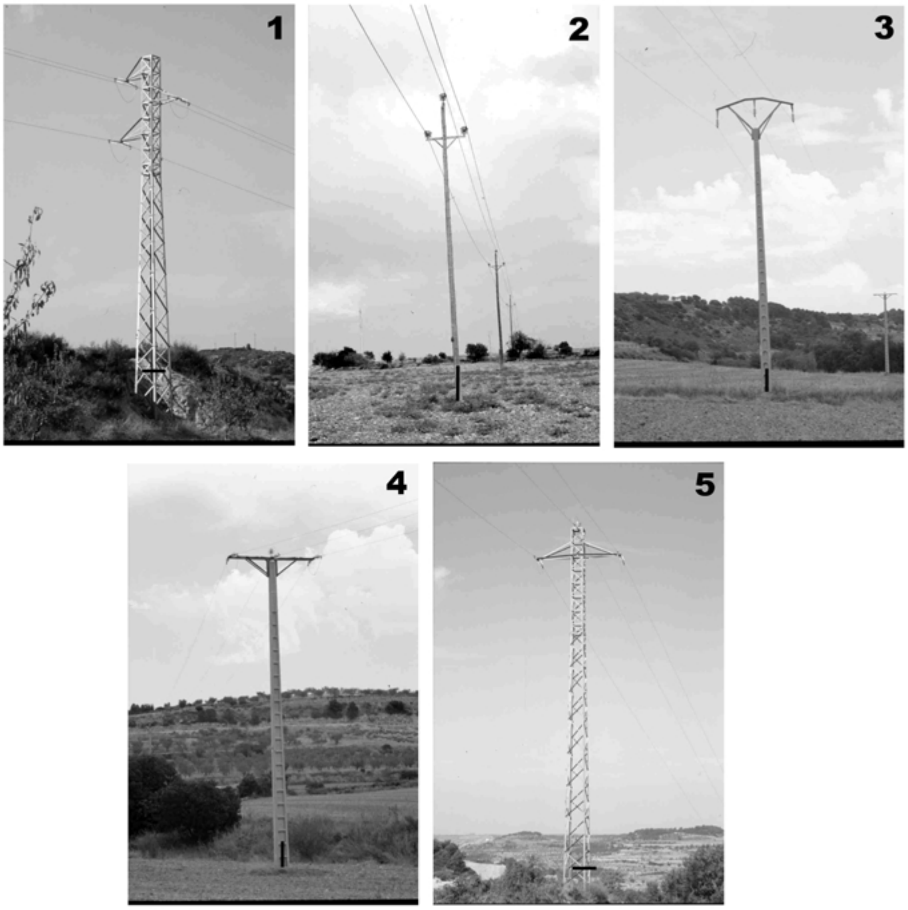

Figure 2. Classification of the types of pylons found in the study area. See also Table 1. 1) Vertically arranged: metal pylons with suspended pin-insulators or jumpers. 2) Cross: wood or concrete cross-shaped pylons with exposed pin-insulators or jumpers. 3) Vault: metal or concrete vault-shaped pylons with suspended pin-insulators or jumpers. 4) Flat: metal or concrete flat-shaped pylons with two distal suspended jumpers and one central exposed jumper. 5) Crossbow: metal cross-shaped pylons with two distal suspended and one central exposed jumpers. The black line on each picture is 1 m long.

the number of levels for a given original variable. As a result of this coding scheme, one new variable was created for all but one of the categories of the original variables. The category for which no variable is created is called the reference level. For every case, each dummy variable is assigned a value of 1 if the case belongs to the category represented by that variable or 0 if the case does not belong to that category. Once a model has been built, the coefficients *B* for the new variables represent the effect of each category compared to the reference category, which is always assigned a *B* coefficient of 0. The absolute value of the coefficients of the logistic models give an indication of the relative importance of each variable in determining the probability of an event occurring.

Model building requires the researcher to select the set of independent variables that best predict the value of the dependent variable, and to compute the variable coefficients and constants of the resulting model. This is done on the basis of a given set of cases for which both the independent and dependent variables have been measured. This process was done by using the SPSS 9.0 statistical package. The variables to be included in the models were selected by means of a forward iteration process during which one variable is introduced or removed from the model at each step on the basis of a likelihood-ratio test, a test which estimates how the predictive power of the model is improved at each step. Once a model has been built, the probability of an event occurring in a given case can be computed, so that cases can be classified accordingly. Usually, the cut probability value to classify the cases is 0.5. In our case, that meant that pylons with $P < 0.5$ would be considered as safe and pylons with $P \geq 0.5$ would be considered as dangerous. However, to reduce the negative consequence of misclassifying a dangerous pylon (classifying a pylon as safe when it is in fact dangerous is worse than classifying a safe pylon as dangerous) I used the cut value of 0.2 to assign pylons to the 'safe' or 'dangerous' categories.

The efficiency of four models in identifying dangerous pylons was compared. The first one (model 1) assumes that no previous inspection under the lines has been

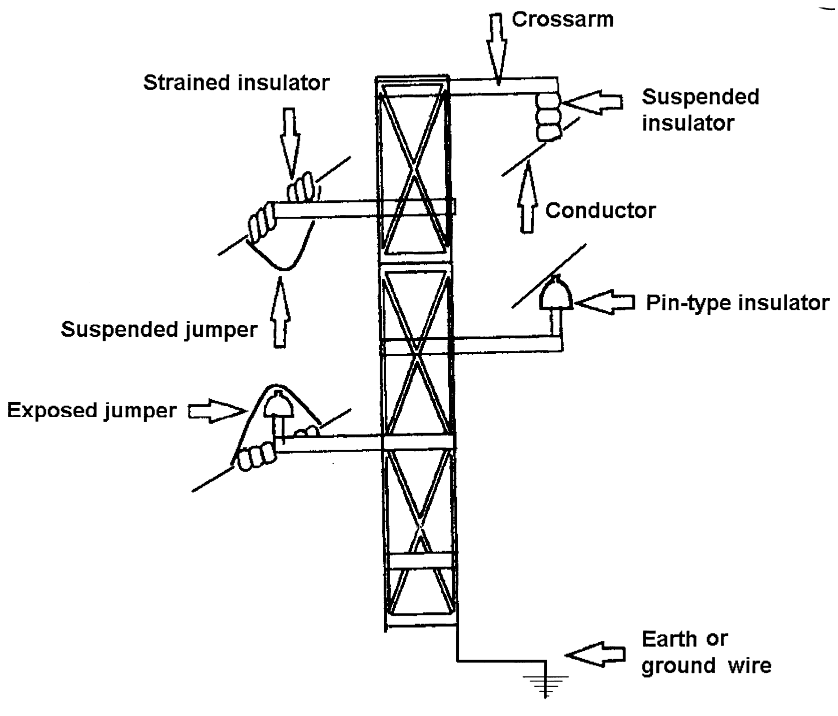

Figure 3. Description of the technical terms used in the text. Modified from Janss and Ferrer (1999a).

made, so no information about the incidence of electrocution in the area is available. This model takes into account only the technical and habitat features of the pylons. The second model (model 2) incorporates the 'bird of prey score' of the area (low, medium, high), based on the presence or abundance of sensitive species in the area. The third model (model 3) does not use information about the area, but incorporates information about the presence of dead birds around neighbouring pylons, obtained after a systematic under-line search has been made. The fourth model (model 4) evaluates the use of all the previous information together. Finally, I tested the ability of a model based on information collected during a single under-line inspection to predict where future mortality may occur. A logistic model identical to model 4 but based only on information collected during the first inspection of the pylons was built (test model) and used to identify dangerous pylons which were missed in the first visit. The predictions of this model were compared with results from later visits to the pylons, so that the efficacity of this strategy could be tested.

Results

Overall electrocution rates and patterns

We found 160 dead birds (60% accipitriformes, 36% corvidae, and 4% strigiformes, Figure 4), concentrated on 67 (13%) pylons (1–12 victims per pylon, Figure 5). Electrocution rates and the number of species involved (Figure 4) were higher in the Llobregós subarea and lowest in Ondara (Table 2). Half of the casualties took place on only 2% of visited pylons, and 50% of the killing pylons accumulate 80% of victims (Figure 6). The risk of electrocution was very low in unearthed or vertically arranged pylons, as well as next to urban areas, and was maximum in earthed crossbow designs, in derivation pylons or in pylons set in natural habitats. Pylons in prominent positions also had higher electrocution rates. The average number of victims per pylon visited and year ranged from 0.10 for all pylons to 0.40 for killing pylons only (Table 3).

Identifiying killing pylons by means of line inspections

Among pylons causing electrocutions, 85% ($n = 67$) had at least one victim below them on the first inspection. The pylons resulting in the most casualties (4–12 accumulated victims, $n = 12$) all had victims found on the first visit (Figure 7). Most of the less dangerous pylons (1–3 accumulated victims, $n = 55$) also had carcasses on the first visit (82%) and, in any case, the first casualty was always detected no later than on the fourth visit. Of the pylons at which more than one visit was conducted, pylons with victims on the first visit ($n = 51$) produced victims in subsequent visits more frequently (29%) than pylons where no victims were found on the first visit (7%, $n = 149$) ($\chi^2 = 15.89$, df = 1, $P = 0.0001$). Of the 24 pylons which received

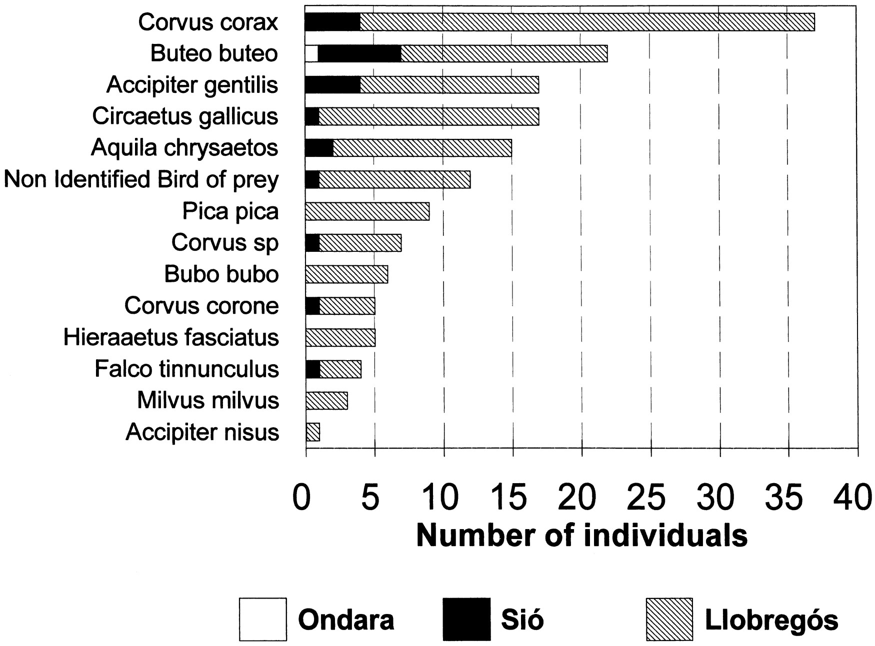

Figure 4. Species frequency distribution of the birds found electrocuted, sorted by subareas.

at least four visits, victims were found on the first inspection at 14 of them; victims were not found until a later inspection at 4 of them; and no victims were found at the remaining 6. From these data, we can estimate that 4 of 18 (22%) of these potentially

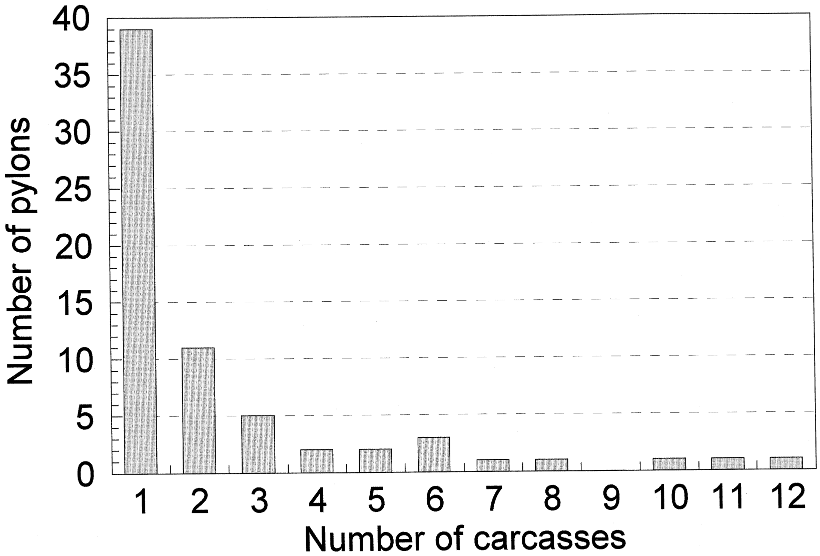

Figure 5. Frequency distribution of the number of victims found under the pylons.

Table 2. Number of pylons causing bird electrocutions and number of victims produced by several types of pylons according to the different variables considered in this study.

	N	Killing pylons (*n*)	Pylons (%)	Carcasses (*n*)	Kill rate (victims/pylon)
FUNC					
Holder	382	43	11	107	0.28
Derivation	44	14	32	40	0.91
Dispositive	81	10	12	13	0.16
MATE					
Unearthed	136	1	1	1	<0.01
Earthed	218	29	13	45	0.21
Metal	153	37	24	114	0.74
MODEL					
Vertically arranged	45	1	2	1	0.02
Cross	123	3	2	6	0.05
Vault	81	9	11	15	0.18
Flat	193	25	13	51	0.26
Crossbow	65	29	45	87	1.34
INSU					
Suspended	130	12	9	18	0.14
Exposed	377	55	15	142	0.38
HABI					
Urban	16	0	0	0	0.00
Crop	339	26	8	52	0.15
Natural dry pasture	72	17	24	38	0.53
Open wood	80	24	30	70	0.87
TOPO					
Non-prominent	436	44	10	87	0.20
Prominent	71	23	32	73	1.03
AREA					
Low score (Ondara)	131	1	1	1	<0.01
Moderate score (Sió)	198	11	6	21	0.10
High score (Llobregós)	178	55	31	138	0.78

dangerous pylons would have passed undetected in a single visit. It can be estimated that a single inspection would have identified 78% of most dangerous pylons which, according to Figure 6, are responsible for a maximum of 91% of casualties. Four of the five Bonelli's eagle found during our study were detected on the first visit to four different pylons accumulating 1, 4, 5 and 8 carcasses. The remaining was not found until the third visit to a pylon which produced no other victims.

Identifiying dangerous pylons by means of logistic models

The high absolute values of the coefficients for habitat and geographical location variables in relation to technical features in all models (Table 4) revealed that these two factors have a large influence in determining the electrocution risk. Model 1, based on technical and habitat features around the pylons, had a high misclassification

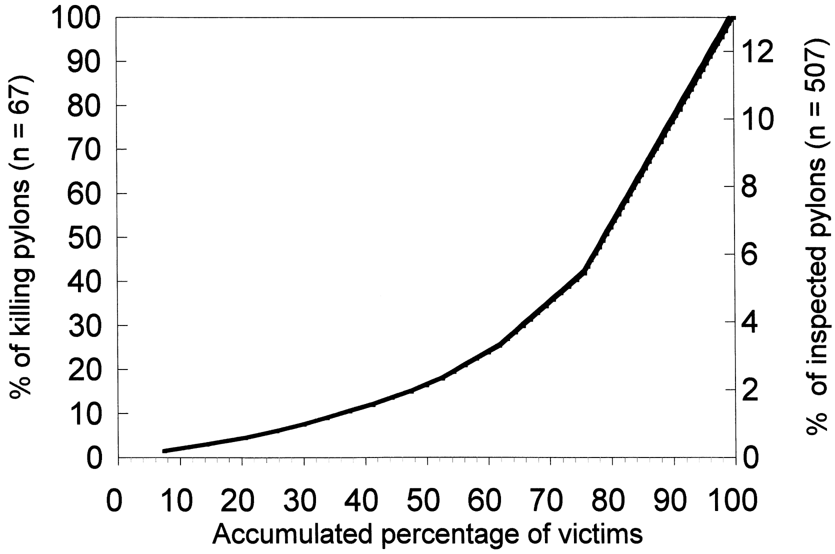

Figure 6. Percentage of killing pylons (left *y*-axis) or visited pylons (right *y*-axis) producing a given accumulated percentage of victims. The accumulated number of victims was computed by sorting the pylons descendently according to the total number of carcasses found in each.

Table 3. Average electrocution rates (birds · visit^{-1}) in the study area in relation to the total number of visits (first column) or only to visits of pylons where victims were found.

	All visits (n = 804)	Only visits to killing pylon (n = 196)
All carcasses (n = 160)	0.21	0.82
Carcasses <1 year old (n = 79)	0.10	0.40

rate, since 36% of the killing pylons in our sample were classified as safe. Including information about the subarea where the pylons are found (model 2) improved the performance of the model which, however, still failed to correctly classify 25% of the dangerous pylons in our sample. A model using information about the presence of carcasses in neighbouring pylons instead of information about the subarea produced similar results (model 3), and a model using both kinds of information (model 4) reduced misclassification rates of killing pylons to only 13%. The test model misclassified 26% of the pylons with victims found on the first visit. However, it performed reasonably well in predicting future casualties in pylons without victims during the first inspection. Of the 149 pylons without victims in the first inspection that received a later visit, the model correctly classified 8 of the 10 pylons where carcasses were subsequently found and 110 of the 139 pylons where no carcasses were subsequently found (χ^2 = 14.45, df = 1, P = 0.0001).

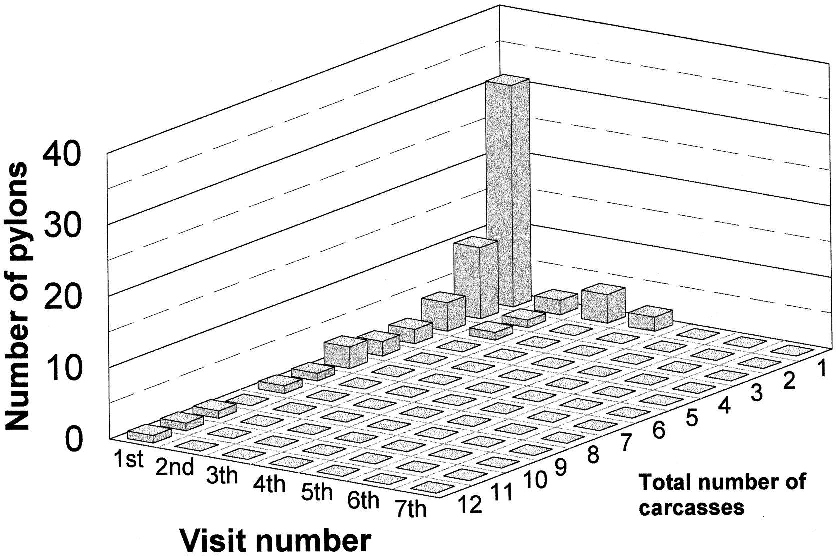

Figure 7. Number of killing pylons identified as such in the *n*th inspection, according to the accumulated total number of victims at each pylon. A killing pylon is identified when one or more carcasses are found below it.

Discussion

The number of victims caused by electricity pylons in the study area was high, especially considering that a large number of victims might have passed undetected (Ferrer et al. 1991). Technical design is what makes pylons potentially dangerous for birds (Bevanger 1994). Vertically arranged pylons or unearthed pylons caused virtually no accidents, while earthed crossbows appeared as the most lethal, followed by flat pylons with exposed jumpers. Vault pylons with suspended insulators or jumpers, which are usually considered as fairly safe (Onrubia et al. 1997; Guzman and Castaño 1998), appeared nearly as dangerous as the latter. However, univariate analysis and logistic models showed that geographical location and habitat setting are very important parameters in determining the actual risk of electrocution posed by a potentially dangerous pylon, because these factors determine the frequency by which pylons are used. Similarly to what has been found in other studies, pylons in areas with high bird of prey populations (Janss and Ferrer 1999b), pylons in prominent positions (Benson 1982), and pylons set in open natural vegetation habitats (Guzman and Castaño 1998) accumulate the highest electrocution rates.

Because the technical characteristics of the pylons determine their potential to kill birds (Bevanger 1994; Guzmán and Castaño 1998), the simplest strategy to eliminate bird electrocution would be to correct all technically dangerous pylons (strategy 1, Table 5). This strategy would virtually eliminate all electrocutions in a given area

Table 4. Equations to compute Z values as a function of the dummy variables originated after coding the variables HABI, MODEL, FUNC, AREA and NEIG. Z values are computed by assigning to every dummy variable a value of 1 if the case belongs to the category represented by that variable, or 0 otherwise. See text for detailed description of the models and variables. True positives refer to dangerous pylons which are classed as dangerous by the model, and false positives to safe pylons which are classed as dangerous by the model.

Model 1: True positives: 64%; false positives: 18%; $\chi^2 = 100.36$, df = 9, $P < 0.0001$
$Z = -10.49 + 5.65$ crop $+ 6.99$ pasture $+ 7.21$ woodland $+ 0.39$ cross $+ 2.09$ vault $+ 2.07$ flat $+ 3.77$ crossbow $+ 1.23$ derivation $+ 0.38$ dispositive
Model 2: True positives: 75%; false positives: 11%; $\chi^2 = 155.19$, df = 11, $P < 0.0001$
$Z = -14.59 + 5.85$ crop $+ 8.04$ pasture $+ 6.91$ woodland $+ 1.17$ cross $+ 2.41$ vault $+ 2.65$ flat $+ 4.07$ crossbow $+ 1.23$ derivation $- 0.13$ dispositive $+ 2.81$ moderate score area $+ 4.52$ high score area
Model 3: True positives: 75%; false positives: 12%; $\chi^2 = 151.38$, df = 10, $P < 0.0001$
$Z = -11.03 + 5.44$ crop $+ 6.52$ pasture $+ 6.57$ woodland $+ 0.38$ cross $+ 1.84$ vault $+ 2.17$ flat $+ 3.33$ crossbow $+ 1.39$ derivation $+ 0.12$ dispositive $+ 2.34$ neighbour-yes
Model 4: True positives: 87%; false positives: 14%; $\chi^2 = 172.21$, df = 12, $P < 0.0001$
$Z = -13.7 + 5.20$ crop $+ 7.00$ pasture $+ 6.13$ woodland $+ 1.02$ cross $+ 2.21$ vault $+ 2.65$ flat $+ 3.79$ crossbow $+ 1.29$ derivation $- 0.16$ dispositive $+ 2.37$ moderate score area $+ 3.55$ high score area $+ 1.51$ neighbour yes
Test model: True positives: 74%; false positives: 13%; $\chi^2 = 131.89$, df = 10, $P < 0.0001$
$Z = -12.61 + 5.21$ crop $+ 6.89$ pasture $+ 6.37$ woodland $+ 0.66$ cross $+ 1.38$ vault $+ 1.63$ flat $+ 2.92$ crossbow $+ 2.36$ moderate score area $+ 3.24$ high score area $+ 1.32$ neighbour yes

(97%), but is relatively inefficient because it involves a large investment in pylons that are actually safe, an investment which would be best allocated to other items.

In the study area, electrocution occurs in a fairly aggregated pattern, so the 'preferred pylon' approach (Williams and Colson 1989) could be a better strategy for eradicating electrocutions. The presence of electrocuted birds found during a single inspection of a power line (strategy 2) identified most of these preferred pylons. However, the presence of dead birds must not be the only criterium for undertaking mitigation actions (Janss and Ferrer 1999b). Scavengers may remove corpses (Ferrer et al. 1991); bird distribution and preferences may change over time, or pylons not identified as killers on one inspection may still produce subsequent deaths. In our study, 9% of the electrocutions occurred in pylons with no victims found at the first visit. This residual mortality can be critical for some endangered species such as the Bonelli's eagle. As much as 20% of electrocutions of this species took place at such pylons. Predictive models incorporating geographical and habitat preferences of birds would allow a more efficient identification of the dangerous pylons than the simple presence of carcasses below them. However, the elaboration of such models has proven difficult, due to differences in size and behaviour among species (Janss and Ferrer 1999b). Indeed, in our case, the strategy based on technical and habitat variables (strategy 3) still left about 20% residual mortality.

Table 5. Comparative performance of several strategies to identify and correct killing pylons in a given area. Maximun percentage of mortality eliminated is predicted from Figure 6. See text for detailed descriptions of the strategies.

Strategy	Present poles where correction is needed (%)	Killing poles actually corrected (%)	Maximum mortality eliminated (%)
1) Correct all technically dangerous pylons	67	94	97
2) Correct only pylons with carcasses on a single visit	11	78	91
3) Correct pylons based on technical characteristics and habitat (model 1)	24	59	82
4) Correct pylons based on technical characteristics, habitat and area (model 2)	20	68	87
5) Correct pylons with carcasses and those predicted by a model based on a single visit (test model)	23	96	99

A simple way of overcoming this problem was the inclusion in the models of qualitative information about the presence and abundance of birds of prey. The resulting strategy for applying this model (strategy 4) resulted in a slight increase in the amount of mortality eliminated and, most importantly, reduced the number of pylons to be corrected to obtain that result. However, the best strategy was obtained by conducting a single under-line search and using the information obtained during that visit to build a predictive model for future casualties. Up to 99% of the casualties could be eliminated by correcting pylons predicted by the resulting model, as well as those where victims were actually found (strategy 5). This strategy gives the most satisfactory results in terms of the relationship between the number of pylons needing to be modified and the proportion of mortality eliminated.

In areas with high bird populations and aggregated electrocution patterns, the presence of dead birds is a good indication of preferred poles (Williams and Colson 1989; Olendorff 1993), and can be used to build predictive models about future mortality. Because most lines are periodically surveyed by power line companies, this information would be easy and quick to obtain, in most cases at no additional cost. Obviously, this strategy will not work in areas with low bird populations, low electrocution rates, or less aggregated patterns of electrocution. In these circumstances, pole modification may need to be widespread (Williams and Colson 1989), or be based on better and more species-specific predictive models.

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