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Birds and powerlines in Italy: an assessment

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Summary

Powerlines may pose severe threats to bird populations. We assessed the significance of powerlines as a source of avian mortality within the Italian electric transmission and distribution system. We reviewed data from 11 mortality censuses and compiled a list of species that were found among powerline victims in Italy, based on over 1,300 reported individual casualties. Overall, 95 species of birds were reported among powerline victims (19% of Italy's total species). The number of recorded species was compared with the number of species in the Italian list, after grouping species based on morphology and ecology. Some groups (e.g. raptors, herons, storks and allies) were highly affected, while others (e.g. passerines and allies) appeared to be poorly represented among species involved in powerline accidents. Furthermore, we evaluated the validity of a published discriminant model for the classification of bird species as collision or electrocution victims according to body measurements. The application of the available model classified 54.7–73.5% of Italian species correctly (depending on the species included), compared with 88.6% of the original dataset. Two new discriminant models based on Italian powerline casualties classified 80.9–81.1% of species correctly. This approach can be a useful tool in assessing collision and electrocution risk for species in different geographical areas. While we recognize the need for a general preventive approach for reducing the bird–powerline conflict, our review highlights once more the importance of local situations, where powerlines may have a strong impact on avian communities.

Introduction

Man-made alterations to natural habitat and landscape increased greatly during the twentieth century, leading to an ever-growing impact on wildlife. Among animals, birds have been forced to confront two main man-made structures: roads and overhead wires (powerlines, fences, telegraph wires, TV-towers, wind-power plants, etc.) (Hodson and Snow 1965, Janss and Ferrer 1999a, Erickson *et al.* 2001). In developed countries in particular, the spread and profusion of powerlines (e.g. an average 2.6 km of powerline/km^2 in Italy; Garavaglia and Rubolini 2000) make them a potential threat for a wide range of bird species, including up to 7% of the SPEC (Species of European Conservation Concern; Tucker and Heath 1994).

Mortality due to powerlines may occur in two ways: collision and electrocution. Different species are vulnerable to each of these two causes of death: death due to collisions affects mainly night migrants and birds with low flight manoeuvrability (low aspect ratio), with heavy body and short wings; electrocution affects mainly raptors and storks (Bevanger 1998). The probability of electrocution for a given species is directly related to its behaviour and size, larger birds being more easily electrocuted than smaller ones (Bevanger 1998, Janss 2000). Preventing electrocution on powerlines is possible, mainly with the installation of electrocution-safe poles or other power-insulating devices (Bevanger 1994, Janss and Ferrer 1999b, Lehmann *et al.* 1999). Collisions can be reduced, but not eliminated unless wires are buried underground (e.g. Morkill and Anderson 1991, Alonso and Alonso 1994, Brown and Drewien 1995, Janss and Ferrer 1998). Many studies have tried to assess the impact of powerlines on bird populations, and some general conclusions can be drawn. Mortality due to collisions seems to be of little biological significance on a large ecological scale (Alonso and Alonso 1999) but can have deleterious effect at a local scale (e.g. Heijnis 1980, Janss and Ferrer 2000) and, coupled with other unnatural causes of death (e.g. poaching or hunting), may seriously affect population dynamics of some species (for a case study on tetraonids see Bevanger 1995). On the other hand, mortality due to electrocution can have significant effects on populations of some groups of species (raptors and storks). It has directly affected population structure and been among the causes of decline in White Stork *Ciconia ciconia*, Spanish Imperial Eagle *Aquila adalberti* and Bonelli's Eagle *Hieraaetus fasciatus* (Rieger and Winkel 1971, Fiedler and Wissner 1980, Crivelli *et al.* 1988, Ferrer and Hiraldo 1992, Mañosa and Real 2001, Real *et al.* 2001).

In this study we present an overview of bird–powerline interactions in Italy, a country where research on this subject has been largely neglected until recently (Garavaglia and Rubolini 2000, Rubolini *et al.* 2001, Sergio *et al.* 2004). First, we review data from 11 mortality censuses (both collision and electrocution), and derive a minimum mortality rate for the investigated powerline sections. Then, based on over 1,300 reported casualties from all over the country, we compile a check-list of species found among powerline victims, in order to identify which groups of species among Italian birds are most affected. Finally, we use this sample of species to validate the discriminant functions proposed by Janss (2000) for the separation of collision and electrocution victims based on species-specific morphological characters.

Materials and methods

Avian mortality censuses and mortality rates

The census of birds found dead under powerlines presents several methodological problems (removal of carcasses by scavengers, crippling bias, observer detection bias) that may add considerable variability to the estimates (Bevanger *et al.* 1994, Bevanger 1999). Due to these possible pitfalls, the calculation of true strike or electrocution rates is very difficult to achieve (Bevanger 1999).

Mortality censuses analysed in this study were carried out mainly by LIPU and CESI staff, while other data refer to published studies. Both high-voltage (HV, 40–380 kV) and medium-voltage (MV, 1–40 kV) powerlines were censused, and in one instance both collision and electrocution accidents were recorded along the same line (Lomellina; see Table 1). The base of power poles was carefully searched for electrocuted birds, whereas the ground section under aerial cables was scanned for collision accidents (Bevanger 1999). For each census we calculated a minimum mortality index (MMI), expressed as the estimated number of birds found dead per kilometre of powerline per year. As the number of reported casualties could not be corrected for possible biases, results should be taken as a minimum estimate. Although mortality rates may be affected by the application of correction factors, these were not available for our study sites.

Table 1. Results of mortality censuses in Italy.

Site	Powerline		No. of birds	Duration of census (days)[a]	MMI	Habitat
	Type	Length (km)				
Collision						
1. Lomellina	MV	10.5	7	–	0.7	Intensive lowland farmland (rice-fields)
2. Valle Sottolido	HV	0.5	0	30	0.0	Wetland and farmland (poplar plantations)
3. Cava Pianetti	HV	0.4	61	640	86.9	Coastal wetlands with extensive reedbeds
4. Molentargius 1[b]	HV	10.5	411	730	19.6	Open coastal wetland
5. Molentargius 2	HV	5.8	209	365	36.3	Open coastal wetland
Electrocution						
6. Lomellina	MV	10.5	32	–	3.0	Intensive farmland (rice-fields)
7. Cuneese	MV	5.1	10	365	2.1	Farmland with hedgerows and trees
8. Comacchio	MV	0.5	1	48	15.2	Open coastal wetland (former saltpans)
9. Ferrara[c]	MV	2.0	41	–	20.5	Farmland with scattered trees
10. Valle Mandriole	MV	3.4	3	45	7.3	Wetland with extensive reedbeds and farmland
11. Pianura bolognese[d]	MV	22.0	52	335	2.6	Intensive farmland (cereal crops)

MV, medium-voltage; HV, high-voltage; MMI, Minimum Mortality Index (birds found per kilometre of powerline per year).

[a] For missing durations see Methods.

[b] Secci (1982); [c] Chiozzi and Marchetti (2001); [d] Chiavetta in Penteriani (1998).

Visits were carried out at variable intervals (usually monthly, at least for the long-lasting censuses). For the Lomellina and Ferrara censuses (see Table 1) the estimation of MMI was done at a single visit per line in late autumn–winter, by recording all the carcasses and remains that were judged to be killed within the current year of census (for a detailed discussion on the reasons why the data from a single visit can be extended to the previous part of the year see Garavaglia and Rubolini 2000 and Chiozzi and Marchetti 2001).

List of bird species involved in powerline accidents

Records were obtained from a wide range of published and unpublished sources, mostly from between the late 1970s and 2001. Unpublished data were collected through a request for information widely circulated among professional and amateur ornithologists, local sections of bird conservation societies and wildlife services. To analyse whether some bird groups were more affected than others in terms of species number, we established eight broad species categories, according to morphology and ecological requirements (abbreviations in parentheses): waterfowl and allies (WAT) (orders *Gaviiformes, Anseriformes, Podicipediformes, Pelecaniformes*); herons and allies (HER) (*Ciconiiformes, Phoenicopteriformes*); waders and gulls (WAD) (*Charadriiformes*); cranes and allies (CRA) (*Galliformes, Gruiformes*); diurnal raptors (RAP) (*Falconiformes, Accipitriformes*); owls (OWL) (*Strigiformes*); passerines and allies (PAS) (including *Passeriformes, Apodiformes, Piciformes, Columbiformes, Caprimulgiformes*) and others (all other orders than those indicated). The proportion of species reported among powerline casualties for each group was compared with the expected number of species for each group based on the Italian list (Brichetti and Massa 1998), by means of a χ^2 test.

Type of mortality and body size

Based on available data, we determined whether a species was an electrocution victim or a collision victim. Species recorded as victims of both collision and electrocution were assigned to a mixed group, following Janss (2000). For a limited number of species we could not obtain information on the exact cause of death: these were assigned to a given category based on morphological and behavioural similarity with a categorized species (see Appendix). We aimed to validate the discriminant model proposed by Janss (2000) for predicting the likelihood that a given species belongs to one of these groups based on four body measurements (body, wing and tail length, body mass). The original discriminant function model (hereafter the Spanish model) was built on a sample of 44 species, for which the author provided observed mortality and mortality risk due to powerlines (collision and electrocution) from a detailed powerline survey in central Spain (Janss 2000). Species in the Spanish sample were assigned to categories based on observed casualties or according to species of similar morphology, if they were observed along powerlines but not recorded among casualties (see Janss 2000). To classify our species sample according to the Spanish model, we first recorded body, wing and tail length (cm) and body mass (g) for all species (taken from Cramp 1998 and other unpublished sources). Data were ln-transformed (except tail length) (see Janss 2000). Then, we recalculated the Spanish discriminant function, using data presented in Janss (2000) and the original data used for that study (courtesy of G. F. E. Janss): this was necessary in order to apply it to our set of species and compare predicted mortality type based on the model with observed mortality in Italy. Assignment of species in our sample to one of the three groups was based on Bayes' rule, using SPSS 10.0 software (see Norusis 1992 for details).

Results

Mortality censuses

Censuses were carried out at 10 sites (Table 1, Figure 1) and a total of 827 birds was found. Mortality rates (MMI) were extremely variable, ranging from 0 to 86.9 dead birds per kilometre of powerline per year in the case of collision censuses, and from 2.1 to 20.5 dead birds per kilometre per year for electrocution censuses. While it seems meaningless to produce a mean value for collision censuses, median electrocution rate for the surveyed lines (excluding the Ferrara census) was 3.0 dead birds per kilometre per year or 0.15 dead birds per pole per year (assuming one pole each 50 m of MV powerline; Garavaglia and Rubolini 2000).

The species composition of electrocution and collision censuses differed considerably according to eco-morphological groups (Figure 2; $\chi^2 = 423$, $df = 6$, $P \ll 0.001$). In particular, electrocution affected mainly corvids (PAS) and diurnal raptors (RAP), while collision affected mainly herons (HER, mainly Greater Flamingo *Phoenicopterus ruber*) and passerines (PAS, mainly Starling *Sturnus vulgaris*). The species composition varied considerably between sites, probably in accordance with varying environmental conditions and to the species' local relative abundance (see Garavaglia and Rubolini 2000 for details).

List of powerline casualties

A total of 1,315 individual powerline casualties of 95 species (19% of the Italian avifauna) was detected in the published literature or reported after the request for information (see list in Appendix). As the data were gathered from different sources and mainly refer to occasional observations (53.2% unpublished data, 45.2% published studies, 1.7% local bird reports), we cannot directly compare the relative abundance at the species level. In any case, a comparison in terms of species number for each of the groups revealed that species from some groups were over-represented among powerline casualties compared with the Italian list (Figure 3; $\chi^2 = 27.6$, $df = 7$, $P = 0.0002$). In particular, the most widely affected groups were OWL and HER (50% of Italian species affected), followed by RAP–CRA (32% and 30% of species respectively) and WAD–WAT (24.5% and 22%, respectively). Within the PAS group, only 10.7% of species was found among powerline victims (Figure 2).

Type of mortality and body size

The recalculation of the Spanish model yielded a discriminant function that correctly classified 86.4% of the Spanish species' sample (the classification success reported in the original study was 88.6%): thus, compared with the data presented in Janss (2000), a single species was misclassified, and we are therefore confident that the recalculation of the discriminant function was successful (the difference resulted from

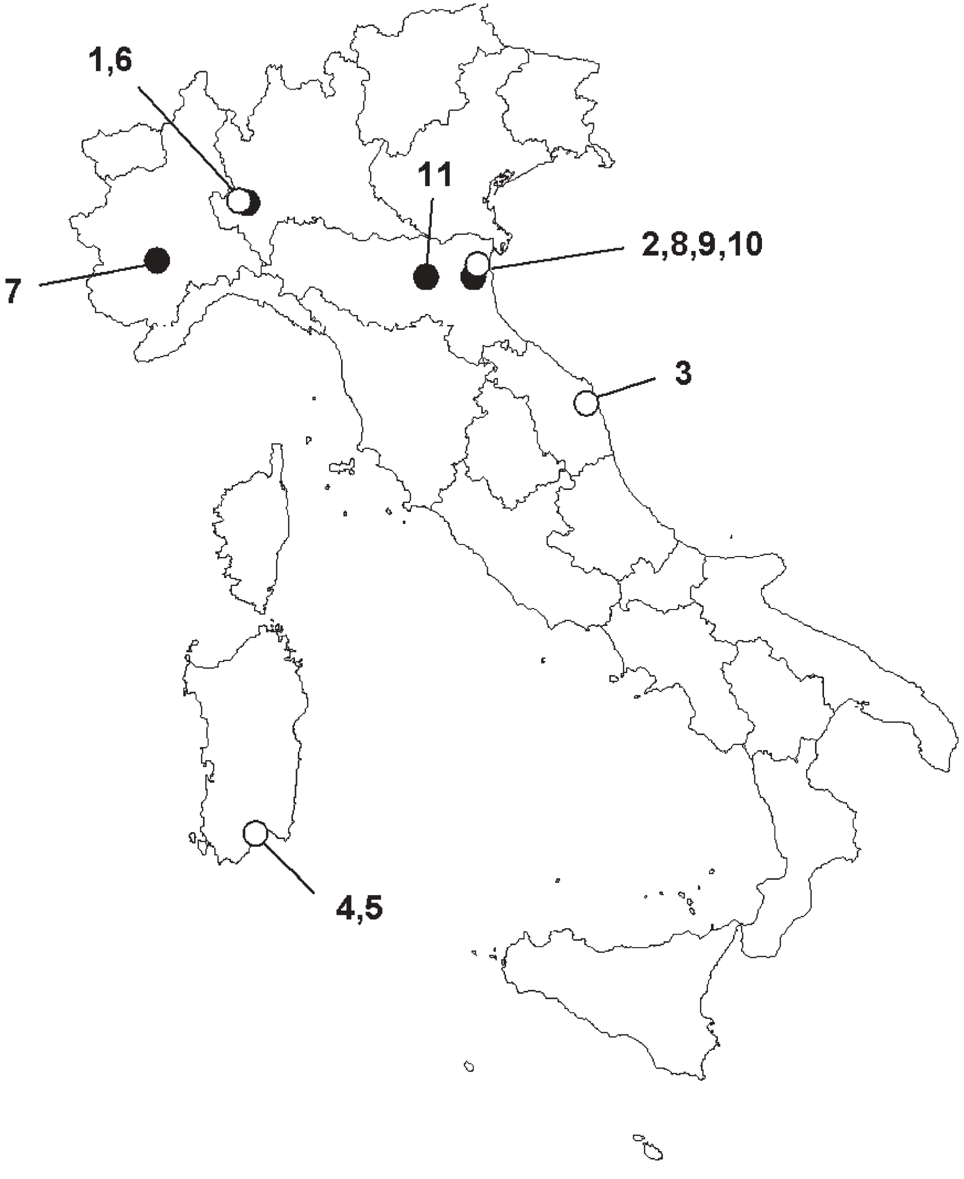

Figure 1. Map of mortality census sites. Open circles, high-voltage lines; filled circles, medium-voltage lines. Site characteristics are reported in Table 1.

minor differences in biometrics between the datasets). The application of the Spanish discriminant function to our species sample ($n = 95$ species, "complete set") classified correctly only 54.7% of species, a significant difference from the Spanish data set ($\chi^2 = 13.8$, $df = 1$, $P < 0.001$). The classification error was distributed equally among all three groups. The predictive power increased significantly to 73.5% if applied to species larger than a Turtle Dove *Streptopelia turtur* (54.7% vs. 73.5%, $\chi^2 = 6.56$, $df = 1$, $P = 0.01$) ($n = 68$ species whose body size was equal or greater than 27 cm,

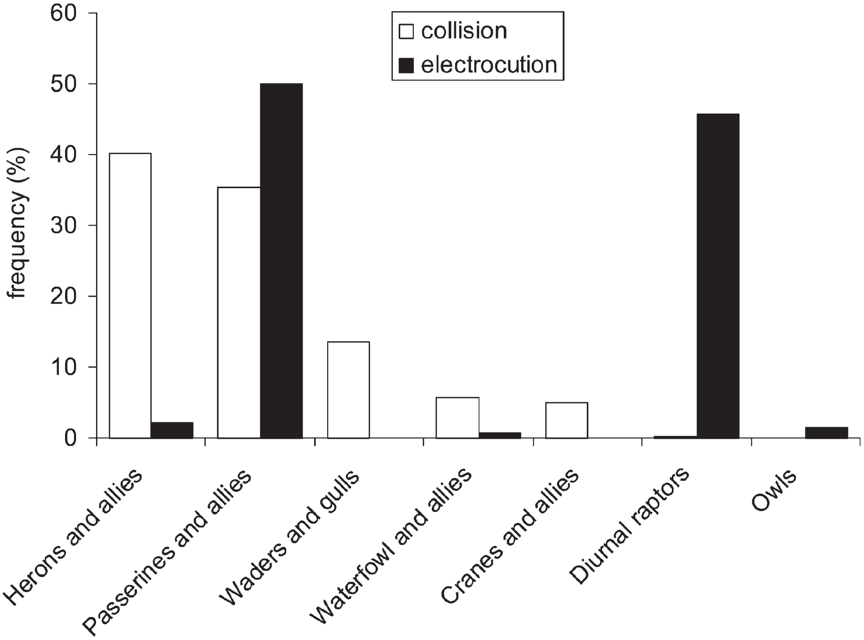

Figure 2. The susceptibility of different avian ecomorphological groups to collision and electrocution, as evidenced by their relative proportions found during collision ($n = 688$ individuals, open bars) and electrocution ($n = 140$ individuals, black bars) censuses (see Materials and Methods for group definitions).

hereafter "reduced set"; after Janss 2000, which considered only these larger species). The classification success of the reduced set was non-significantly lower than that of the Spanish original dataset (73.5% vs. 86.4%; $\chi^2 = 2.50$, $df = 1$, $P = 0.11$). A new discriminant analysis model built on the observed mortality categories for the complete set classified 81.1% of the species correctly, with the first function alone explaining 98.6% of the variance (Table 2). In particular, 62 of 68 collision victims were correctly classified (89.8%), while predictive power was lower for the other groups (53.8% of species in the mixed group and 61.5% in the electrocution group). If the model was built on the reduced set, classification success was slightly lower (80.9%) (Table 2) but the error was more evenly distributed among groups (83.7%, 66.7% and 84.6% of cases correctly classified for collision, mixed and electrocution groups, respectively). The classification success for the reduced set based on this model or on the Spanish model did not differ significantly (80.9% vs. 73.5%; $\chi^2 = 0.96$, $df = 1$, $P = 0.32$). Therefore, a model based on larger species alone, which are nevertheless more frequent among powerline casualties (Figure 3), seems to be more reliable in predicting species-specific probability of collision or electrocution as a source of powerline mortality. In general, for the reduced set, the risk of collision was higher for species with longer tails and wings, while the risk of electrocution was higher for smaller species with shorter tails and wings; species in the mixed group showed intermediate measurements.

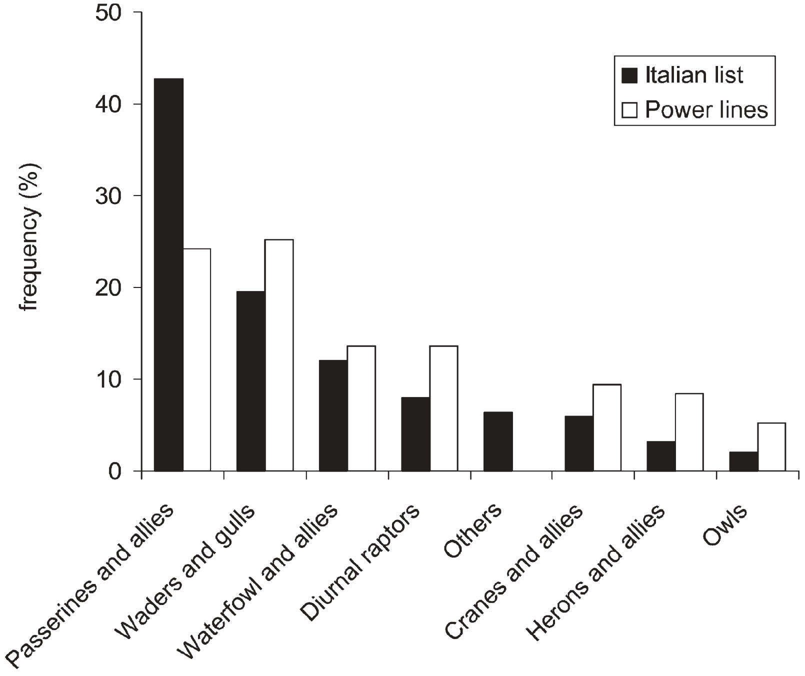

Figure 3. The susceptibility of eight different groups of species of the Italian avifauna to powerline mortality, as evidenced by the relative proportion of species included in the Italian species list (from Brichetti and Massa 1998, $n = 500$ species, black bars) compared with those found to be powerline victims ($n = 95$ species, open bars). Groups of species were defined based on morphology and ecology (see Materials and Methods for details).

Discussion

A broad spectrum of species of the Italian avifauna appeared to be among powerline victims. However, populations of only a fraction of these are likely to be significantly affected. For example, the Italian breeding population of Greater Flamingo was negatively affected by powerlines close to the few saltmarshes holding colonies: up to 5% of colour-marked juvenile birds born at the largest colony in Sardinia were found dead beneath HV wires crossing wetlands around the colony (Garavaglia and Rubolini 2000). Further, powerlines were the main cause of unnatural mortality for Eagle Owl *Bubo bubo* breeding in the Italian mountain areas (Alps and Apennines; Penteriani and Pinchera 1990, Marchesi *et al.* 2001, Rubolini *et al.* 2001, Sergio *et al.* 2004) and Osprey *Pandion haliaetus* migrating through Italy from Scandinavia (D. Rubolini *et al.* unpublished data). Severe losses were also recorded among the reintroduced White Stork populations in northern Italy (70% of recoveries of ringed birds; G. Vaschetti and S. Fasano, pers. comm.) and both the wild (Sardinia) and restocked (north-east Italy) Griffon Vulture *Gyps fulvus* populations (Garavaglia and Rubolini 2000). Some other species of Italian and European conservation concern and/or extremely scarce/localized in Italy were also detected among occasional victims (e.g. Bittern *Botaurus stellaris*, Purple Gallinule *Porphyrio porphyrio*, Little Bustard *Tetrax tetrax*; see Appendix for the complete list of species).

Table 2. Results of a discriminant function analysis to separate species according to the type of powerline mortality (collision, electrocution or mixed group, including both collision and electrocution victims) based on their morphology. Raw (standardized) coefficients of discriminant functions, and statistics for differences in mean character values between groups (Wilks' Lambda and ANOVA) are shown.

Variables	Coefficients		Statistics		
	Function 1	Function 2	Wilks' Lambda	*F*	*P*
*Complete set (*n = *95 species)*					
Tail length	0.16 (0.95)	−0.04 (−0.27)	0.602	30.40	< 0.001
Body length (ln)	−4.30 (−2.24)	−4.56 (−2.38)	0.914	4.35	0.016
Wing length (ln)	1.84 (0.84)	−1.35 (−0.61)	0.774	13.41	< 0.001
Body mass (ln)	0.94 (1.25)	2.50 (3.32)	0.870	6.90	0.002
Constant	2.53	7.00			
*Reduced set (*n = *68 species)*					
Tail length	0.15 (0.96)	−0.02 (−1.05)	0.659	16.84	< 0.001
Body length (ln)	−4.33 (−1.71)	−3.50 (−1.38)	0.996	0.13	0.876
Wing length (ln)	2.11 (0.77)	−1.45 (−0.53)	0.856	5.46	0.006
Body mass (ln)	0.60 (0.60)	2.38 (2.38)	0.973	0.91	0.409
Constant	3.85	3.50			

"Complete set" analysis includes all the 95 species recorded as powerline casualties in Italy, while the "Reduced set" analysis includes 68 species (those larger than a Turtle Dove *Streptopelia turtur*, i.e. species whose body length was ≥ 27 cm, following Janss 2000). All morphological variables (except tail length) were ln-transformed (results were qualitatively identical if tail length was ln-transformed). Function 1 accounted for most of the between-group variability in both analyses (98.6% and 99.2%, respectively). The classification success (based on Bayes' rule) was 81.1% and 80.9% for the two sets of data, respectively.

As in previous studies (e.g. Ferrer *et al.* 1991, Bevanger 1998, Janss 2000, Janss and Ferrer 2001), some groups were more affected than others: in particular, collision affected large species characterized by a low flight manoeuvrability (cranes, herons and allies), while many diurnal and nocturnal raptors and corvids were affected by electrocution. Passerine species and allies were relatively less affected by powerline mortality than other groups, probably due to their generally small body size and high flight manoeuvrability (Bevanger 1998, Janss 2000).

The discriminant model proposed by Janss (2000) for predicting the probability of a given species being among electrocution or collision victims based on morphology performed fairly well with Italian data, classifying a maximum of 73.5% of species correctly. This discrepancy may be related to differences in species categorization in the two studies: Janss' (2000) categorization was based both on observed casualties and on *a priori* morphological groups potentially differing in susceptibility to powerlines, whilst our classification was based on observed mortality alone. Therefore, in Janss's study, a few waders, which tend to have thin, small wings compared with body size and, according to Bevanger (1998), may be theoretically susceptible to both collision and electrocution, were assigned to the mixed group, while in our study they were recorded among collision victims only, and this may explain the low predictive power of the Spanish functions when applied to the Italian dataset. Moreover, a cautionary note on the discriminant model approach should be added: the models do not perform well if small species, mainly recorded as collision victims, are included, as shown by the low classification success of the Spanish model on the complete Italian set of species. Anyway, our study confirms that predictive discriminant models can provide a useful tool for analysing objectively the susceptibility of a given species to collision or electrocution risk. This may be especially useful in developing countries with increasing levels of electrification and high levels of avian biodiversity for predicting, and therefore reducing, the impacts of powerlines on local avifaunas (Bevanger 1998, Janss 2000).

Mortality rates derived for Italian powerlines showed a high variability, mainly related to site-specific characteristics and technical properties of powerlines, as mortality due to powerlines appears to be heavily influenced by surrounding landscape features (Bevanger 1990, Janss and Ferrer 2001). Censused sections were not distributed at random within the electric system: they can be considered "worst-case studies", which are of limited statistical and general value, and ultimately cannot be used to derive estimates of powerline mortality over the whole Italian transmission and distribution network (Bevanger 1999). Most collision censuses were carried out on marshlands, where birds are more concentrated, hence potentially inflating the overall collision rate (e.g. Hejniis 1980). On the other hand, electrocution censuses were carried out in cultivated farmland, a typical and widespread situation of the country's landscape crossed by MV distribution powerlines. Although data from other studies are difficult to compare (Janss and Ferrer 1999c), some estimates of electrocution rates are available from selected powerlines in both Spain and the United States: our estimate (0.15 dead birds per pole per year) is in line with the recent Spanish calculations (0.21 dead birds per pole per year; Janss and Ferrer 1999c), while it is generally lower than that recorded in the United States (0.15–5.2 dead birds per pole per year; see references in Janss and Ferrer 1999c). This may be related to an overall low density of some species considered to be vulnerable to the powerline risk in the Italian territory, and a lower diversity of large diurnal raptors (compared with North America), raptors being among the main victims of electrocution. The estimated minimum number of electrocuted birds may be considerably altered by the application of a correction factor for carcass removal by avian and mammalian scavengers. True mortality rate may be up to 60% higher for a mortality census carried out at monthly intervals, depending on, for example, the species concerned, frequency of visits, density of scavengers and site characteristics (Ferrer *et al.* 1991, Bevanger 1995, Alonso and Alonso 1999, Janss and Ferrer 2001).

While it may be tempting to infer that mortality due to powerlines is of little overall biological significance in Italy (e.g. Alonso and Alonso 1999), it is clear that not all species are equally involved, and that raptors and other slow-reproducing, long-lived and large-sized (*k*-selected) species, many of which are considered of high conservation priority, are over-represented among casualties. For rare and localized raptors, the regular death of even a few adults and dispersing juveniles may have marked consequences on population structure, increasing turnover rates of territories and the proportion of immature breeders, and ultimately leading to a decreased reproductive output and population declines (e.g. Ferrer and Hiraldo 1992, Mañosa and Real 2001). Furthermore, deleterious effects were recorded in local situations, where huge numbers of raptors may congregate due to increased food availability (Chiozzi and Marchetti 2001), and considerable damage was also recorded among restocking projects of endangered large birds (storks and vultures).

In conclusion, a degree of avian mortality appears to be intrinsic in the aerial electric system, and efforts by power companies should be concentrated on implementing strategies of mitigating actions, perhaps based on targeted measures at high-priority sites (in the case of collision) and modification of dangerous power pylons, rather than implementing large-scale mitigation actions which may be ineffective in reducing powerline mortality (e.g. Mañosa 2001). Locally, the impact of powerlines is evident and can be of serious conservation concern for local populations of a species and for species with a restricted distribution. Future efforts to reduce avian mortality by power companies should include a larger use of the widely available electrocution-safe structures on distribution MV powerlines, and careful siting through a preliminary evaluation of alternative tracks for HV transmission lines: in particular, the localization of new HV lines in areas known to be hosting high-priority species at elevated collision risk should be carefully avoided, with particular reference to areas where reintroduction and/or restocking projects of large species are under way.

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Appendix. Systematic list of species recorded among powerline casualties in Italy (up to the year 2001: see Materials and Methods).

The cause of death is reported (C, collision; E, electrocution; M, collision and electrocution; a, species assigned to a given category based on morphological similarity with a categorized species); *n* represent the number of individuals recorded for each species (overall *n* = 1,315).

Scientific name	Group	*n*	Cause	Body (cm)	Wing (cm)	Tail (cm)	Mass (g)
Gavia arctica	WAT	1	C	65.5	31.7	5.8	2150.0
Tachybaptus ruficollis	WAT	3	C	27.0	10.0	3.0	135.0
Podiceps cristatus	WAT	1	C	48.5	19.0	4.5	673.5
Podiceps nigricollis	WAT	1	C	31.0	13.2	3.5	307.5
Phalacrocorax carbo	WAT	1	C	90.0	34.8	15.2	2254.0
Botaurus stellaris	HER	2	C	75.0	32.9	11.1	1403.5
Nycticorax nycticorax	HER	4	C	61.5	29.1	10.8	636.0
Ardeola ralloides	HER	1	C	45.5	22.1	7.7	288.0
Egretta garzetta	HER	8	C	60.0	27.6	9.6	455.0
Ardea cinerea	HER	8	C	94.0	45.0	17.0	1433.0
Ardea purpurea	HER	6	C	84.0	36.3	12.2	871.5
Ciconia ciconia	HER	57	M	107.5	56.5	22.7	3448.0
Phoenicopterus ruber	HER	296	C	135.0	40.4	14.6	3052.0
Cygnus olor	WAT	3	C	152.5	58.4	21.8	10750.0
Tadorna tadorna	WAT	1	C	62.5	31.9	10.2	996.5
Anas penelope	WAT	1	C	48.0	25.9	9.8	745.0
Anas crecca	WAT	5	C	36.0	18.4	6.6	331.5
Anas platyrhynchos	WAT	29	C	57.5	27.2	8.5	1016.0
Anas acuta	WAT	2	C	58.5	26.8	14.2	793.0
Anas querquedula	WAT	8	C	39.0	19.4	6.4	326.0
Aythya ferina	WAT	2	C	45.5	21.2	5.4	828.0
Milvus milvus	RAP	1	E	63.0	49.7	33.5	1080.0
Gyps fulvus	RAP	15	M	100.0	73.9	30.2	9250.0
Circaetus gallicus	RAP	1	E	64.5	52.9	27.9	1699.5
Circus aeruginosus	RAP	1	C	52.0	40.3	23.2	584.5
Circus cyaneus	RAP	1	C	48.0	35.7	22.8	436.5
Accipiter gentilis	RAP	2	Ma	55.0	33.3	24.0	1135.0
Accipiter nisus	RAP	10	M	33.0	22.2	16.5	204.0
Buteo buteo	RAP	80	E	57.5	39.3	21.2	879.0
Aquila chrysaetos	RAP	4	E	88.0	62.6	32.6	4383.0
Pandion haliaetus	RAP	11	E	56.5	48.2	20.9	1527.5
Falco tinnunculus	RAP	41	E	33.5	25.1	16.7	174.5
Falco subbuteo	RAP	1	Ea	33.0	26.2	13.3	235.5
Falco peregrinus	RAP	2	E	42.0	33.3	15.9	941.0
Tetrao tetrix	CRA	1	C	47.5	24.2	10.0	1090.0
Phasianus colchicus	CRA	1	C	71.0	23.0	40.3	1047.5
Rallus aquaticus	CRA	2	C	25.5	12.1	5.1	121.0
Porzana porzana	CRA	1	C	23.0	12.0	4.7	83.6
Porzana pusilla	CRA	1	C	18.0	9.2	4.3	32.2
Gallinula chloropus	CRA	14	C	33.5	18.1	7.4	273.5
Porphyrio porphyrio	CRA	4	C	47.5	26.2	9.6	796.5
Fulica atra	CRA	20	C	37.0	21.2	5.4	699.0
Tetrax tetrax	CRA	1	C	42.5	24.8	10.4	725.0
Himantopus himantopus	WAD	1	C	37.5	24.0	7.9	205.0
Recurvirostra avosetta	WAD	22	C	43.5	22.6	8.4	309.5
Charadrius alexandrinus	WAD	2	C	16.0	11.2	4.6	43.0
Vanellus vanellus	WAD	1	C	29.5	22.7	10.4	221.5

Appendix. Continued

Scientific name	Group	*n*	Cause	Body (cm)	Wing (cm)	Tail (cm)	Mass (g)
Calidris minuta	WAD	2	C	13.0	9.8	4.0	28.6
Calidris alpina	WAD	2	C	18.0	11.6	4.9	43.0
Philomachus pugnax	WAD	1	C	25.0	17.5	6.0	142.5
Gallinago gallinago	WAD	1	C	26.0	13.4	5.8	113.5
Scolapax rusticola	WAD	2	C	34.0	19.7	8.4	306.5
Limosa limosa	WAD	1	C	42.0	21.3	7.7	317.0
Limosa lapponica	WAD	1	C	38.0	21.7	7.6	315.0
Numenius arquata	WAD	3	C	55.0	30.1	11.1	725.0
Tringa erythropus	WAD	4	C	30.0	16.9	6.4	161.5
Tringa totanus	WAD	1	C	28.0	15.8	6.3	121.0
Tringa glareola	WAD	1	C	20.0	12.8	4.9	67.5
Actitis hypoleucos	WAD	1	C	20.0	11.2	5.3	47.8
Larus minutus	WAD	5	C	26.0	22.2	9.0	129.0
Larus ridibundus	WAD	36	C	35.5	30.1	11.5	288.0
Larus genei	WAD	10	C	43.0	30.3	11.4	249.0
Larus canus	WAD	1	C	41.0	35.1	13.4	386.5
Larus argentatus	WAD	30	M	61.0	44.9	17.4	895.0
Sterna sandvicensis	WAD	1	C	38.5	30.7	7.4	245.0
Sterna albifrons	WAD	2	C	23.0	17.8	4.4	56.5
Chlidonias niger	WAD	2	C	23.0	21.6	6.3	72.7
Columba livia var. domestica	PAS	6	M	32.5	22.4	11.3	293.5
Columba palumbus	PAS	1	Ma	41.0	25.1	16.3	519.5
Streptopelia decaocto	PAS	1	Ma	32.0	18.0	13.9	208.5
Bubo bubo	OWL	169	M	67.5	46.3	25.3	2106.0
Athene noctua	OWL	1	M	22.0	16.5	7.8	191.5
Strix aluco	OWL	7	M	38.0	27.3	15.9	460.5
Strix uralensis	OWL	1	M	61.0	36.1	27.2	730.0
Asio otus	OWL	9	M	36.0	29.7	13.9	282.0
Caprimulgus europaeus	PAS	1	Ca	27.0	19.4	13.7	85.0
Apus apus	PAS	4	C	16.5	17.3	7.5	42.7
Picus viridis	PAS	1	E	32.0	16.4	9.9	193.5
Hirundo rustica	PAS	2	C	18.0	12.1	9.5	19.5
Delichon urbica	PAS	2	C	12.5	11.1	6.1	19.6
Oenanthe oenanthe	PAS	1	C	15.0	9.6	5.3	24.0
Turdus torquatus	PAS	2	C	23.5	14.0	11.1	107.5
Turdus merula	PAS	2	C	24.5	12.6	10.7	107.1
Turdus philomelos	PAS	2	C	23.0	11.5	8.4	81.3
Turdus viscivorus	PAS	2	C	27.0	15.2	11.2	129.0
Acrocephalus scirpaceus	PAS	1	C	13.0	6.6	5.1	12.6
Oriolus oriolus	PAS	1	C	24.0	15.3	8.4	71.4
Lanius collurio	PAS	1	C	17.0	9.4	7.4	30.7
Pica pica	PAS	10	E	45.0	19.9	25.3	226.8
Corvus corone	PAS	2	E	46.0	32.4	18.2	542.0
Corvus cornix	PAS	50	E	46.0	32.4	18.2	542.0
Corvus corax	PAS	1	E	64.0	42.1	22.9	1185.0
Sturnus vulgaris	PAS	245	C	21.5	13.1	6.3	81.3
Sturnus unicolor	PAS	1	C	22.0	13.2	6.3	90.6
Fringilla montifringilla	PAS	1	Ca	14.0	9.0	6.4	22.6