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Corpse removal experiments with Willow Ptarmigan *(Lagopus lagopus)* in power-line corridors

Experimente zur natürlichen Kadaver-Beseitigung entlang Hochspannungleitungen mit Moorschneehühnern *(Lagopus lagopus)*

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Key words: Willow Ptarmigan *(Lagopus lagopus)*, corpse removal experiments, power-line corridors.

Summary

BEVANGER, K., Ø. BAKKE & S. ENGEN (1994): Corpse revomal experiments with Willow Ptarmigan *(Lagopus lagopus).* Ecol. Birds 16: 597-607.
Assessing the number of birds killed by striking power lines is complicated by the fact that the corpses are removed by scavengers. In this paper the collision of birds against power lines and the removal of the corpses by scavengers are modelled. Based on the model, a method for assessing the number of casualties on a given power-line section during a certain period is presented.
The observer patrols the power-line section every few days (not necessarily at regular intervals) counting and removing new victims. During the patrols, dead birds are occasionally placed along the power-line section so that the amount of scavenging of these artificial victims can also be observed. Since the precise time each of the artificial victims was placed is known, information about the rate at which scavengers remove the corpses is obtained.
The method is illustrated by two sets of experiments on power-line sections in Central Norway and Southern Norway, respectively.

Zusammenfassung

BEVANGER, K., Ø. BAKKE & S. ENGEN (1994): Experimente zur natürlichen Kadaver-Beseitigung entlang Hochspannungsleitungen mit Moorschneehühnern *(Lagopus lagopus)*. Ökol. Vögel 16: 597-607.
Die Einschätzung der Zahl der durch Kollision an Stromleitungen getöteten Vögel wird erschwert durch die Tatsache, daß die Kadaver durch aasverwertende Organismen (Mikroorganismen, Invertebraten und Vertebraten) beseitigt werden. In dieser Untersuchung wird ein Modell für diese Beseitigung durch Leitungsanflug getöteter Vögel entlang Hochspannungsleitungen entwickelt. Gestützt auf das Modell wird eine Methode vorgestellt, die Zahl der Vogelverluste entlang eines bestimmten Abschnittes einer Hochspannungsleitung für eine bestimmte Periode abzuschätzen.
Der Beobachter kontrolliert den Leitungsabschnitt im Abstand einiger Tage (in nicht unbedingt regelmäßigen Intervallen), zählt und entfernt dabei die Leitungsopfer. Während dieser Kontrollgänge

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werden tote Vögel wie zufällig entlang dieses Leitungsabschnittes ausgelegt. Dadurch kann die Zahl der beseitigten »künstlichen« Leitungsopfer ermittelt werden. Da für die ausgelegten toten Vögel Zahl und Zeit der Auslegung exakt bekannt ist, können Informationen zur Beseitigungsrate durch Aasverwerter erhalten werden.
Die Methode wird anhand zweier Experimentfolgen an Hochspannungsleitungsabschnitten in Zentral- und Südnorwegen erläutert.

1. Introduction

Despite having generally good vision, birds frequently collide against man-made constructions, like power lines. To judge the biological significance of wire-strike accidents (see, e.g., FAANES 1987), estimates of the number of casualties, locally or regionally, are imperative.
Counting dead birds in the clear-felled area along the power lines is a method frequently used to obtain data on this mortality factor. The observer (together with a dog) walks at intervals in the clear-felled corridor beneath the overhead wires, picking up and counting the corpses or the remains of corpses. Because the remains will eventually be removed by scavengers, the number of casualties may be greater than the number of victims actually found.
The speed at which carcasses of collision victims are removed by the activity of microorganisms, invertebrates and vertebrates is influenced by several factors, e.g. habitat, scavenger activity and season (see, e.g., PUTMAN 1983, who used small mammal corpses to study the overall removal rate). Experiments to try to determine the removal rates of collision victims have been carried out using e.g. House Sparrows *(Passer domesticus)* (DOBINSON & RICHARDS 1964; SCOTT, ROBERTS & CADBURY 1972), Starlings *(Sturnus vulgaris)* (HEIJNIS 1980), ducks and gulls (BEAULAURIER 1981) and chickens *(Gallus* spp.) (LONGRIDGE 1986). In connection with two studies – one in coniferous forest in Central Norway and one in northern boreal birch forest in Southern Norway – to obtain data on collision frequencies involving small species of game birds, experiments were carried out to get information about the local removal rate of the wire-strike victims in an attempt to improve the quantitative estimates of the number of collision victims.
A mathematical model for collision and removal of birds is proposed in this paper. Based on the number of birds actually found during patrols, the model provides an estimate of the number of birds killed in collissions. The model takes into account the scavenging of collision victims and permits the patrols to be undertaken at irregular intervals, although longer intervals decrease the accuracy of the estimates of the collision rate.
The overall mortality and its possible effects on the populations of the tetraonid species in question are discussed in another paper (BEVANGER in prep.).

2. Materials and methods

Two sets of experiments were carried out (Table 1). The first was on sections of 66, 72 and 132 kV power lines in Central Norwegian boreal forest, in areas 5-10 km from cultivated land in a mixture of coniferous and deciduous forest where the power-line corridors cross bogs and some low alpine habitats (BEVANGER 1988). The second was carried out in a mountain valley in Southern Norway on sections of 22, 66 and 300 kV power lines in northern boreal birch forest (BEVANGER & SANDAKER 1993).

Table 1. Data from experiments carried out to examine the removal rate of wire-struck birds in transmission line corridors.

Experiment no.	Location	Date when first placed	Number of birds placed	Date when first patrolled
1	Central Norway	13/01/87	20	08/11/84
2	Central Norway	16/03/87	13	27/02/85
3	Southern Norway	03/10/89	8	03/10/89
4	Southern Norway	28/11/89	10	23/11/89
5	Southern Norway	13/03/90	12	26/02/90

Each experiment consisted of two parts: (1) the placing and monitoring of dead Willow Ptarmigan serving as artificial wire-strike victims, in order to obtain information about the removal rate due to scavenging, and (2) patrols at (not necessarily regular) intervals to count and remove new victims since the last patrol. A placed bird was defined as having been taken by a scavenger when it disappeared or was reduced to minor remains of feathers, that is, when the remains were so scanty that they would not have been interpreted as remains of a collision victim during patrols. In the first patrol of each experiment all corpses were removed from the power-line corridor, and in the subsequent patrols new casualties were counted and removed.

The first experiment set comprises two experiments (nos. 1 and 2). In the first experiment, two power-line sections with a total length of 5.6 km were studied and in the second a 3.2 km section was studied. (The first sections belong to power lines nos. 4 and 7 and the third belongs to no. 4, referring to Bevanger 1988). In both experiments all the corpses were placed on the same day along the entire power-line section used for the experiment, placing a bird between one pylon and the next at each second or third pylon, beneath the overhead lines or a few metres to the side of them. As the distances between the pylons vary, the distances between the birds varied, with a mean distance of 280 m between the corpses for experiment no. 1 and 245 m for experiment no. 2. The removal of the corpses was recorded during the following days (Table 2). In experiment no. 1, the corpses were monitored for only 10 days due to heavy snowfall.

The patrols for collision victims in experiments nos. 1 and 2 actually started about two years before the removal part of the experiments as part of a systematic patrolling programme for selected power-line sections in Central Norway (Bevanger 1988). The removal part of the two experiments was done on the same sections or on sections located close to the patrolled sections, and at the same time of year.

The second experiment set was designed differently, as both parts of the experiment (placing of corpses and patrols for wire-strike victims) were performed simultaneously. The birds were placed randomly (judged subjectively) along the power-line sections, at irregular intervals and at most one on each patrol. There was full snow cover during the whole experiment period and only Willow Ptarmigan in white winter plumage were used. The three power-line sections patrolled are located in a narrow (about 1 km broad) valley system. The 66 and 300 kV sections patrolled (2.5 and 5 km) are parallel (150-300 m apart) on one side of the valley while the 22 kV section patrolled (2.5 km) is located on the other side of the valley (cf. Bevanger & Sandaker 1993).

3. The model

We assume that for a given power-line section and a time interval between two consecutive patrols, the number of birds striking the wires of the line is Poisson distributed with parameter λ. Further, we assume that the "lying time" T of a dead bird is Weibull distributed with parameters $\alpha, \beta > 0$, that is, the probability of the "lying time" being longer than t is $e^{-\alpha t^{\beta}}$. We assume that α and β are constant for each experiment. The Weibull distribution is commonly used in survival analysis (see, e. g., KALBFLEISCH & PRENTICE 1980). We want to estimate the parameters α and β for each experiment. On the basis of these parameters, which contain information about the removal rate and the number of corpses actually found, the collision rate λ may be estimated.

3.1 Estimation of α and β in the Weibull distribution

The parameters α and β of the Weibull distribution were estimated for each of the five experiments by maximum likelihood. Let n denote the number of birds placed. For each bird, say bird no. i, two points of time since the placing were recorded; the last time the bird was still observed, t_i, and the first time it was not seen any more, t'_i. Let $F(t) = e^{-\alpha t^{\beta}}$ for each $t \geq 0$. The probability that a bird is removed in the time interval from t_i to t'_i since it was placed is then $F(t'_i) - F(t_i)$. We can estimate α and β by maximizing the likelihood function L given by

$$L(\alpha, \beta) = \prod_{i=1}^{n} (F(t'_i) - F(_i)),$$

which can be done numerically.

3.2 Estimation of λ in the Poisson distribution

Suppose that x birds are found during a patrol and that time T has elapsed since the last patrol. We would like to have an estimate of the parameter λ of the Poisson distribution from which we imagine the number of wire-strike victims is drawn.
We denote by p the probability that a bird killed by collision in the time interval (of lenght T) between the current patrol and the last, is still present. Then the number of such birds is Poisson distributed with parameter λp (see, e.g., KENDALL, STUART & ORD 1987), and the maximum likelihood estimate of λ turns out to be x/p.

It only remains to find p, which by the law of total probability is $p = \frac{1}{T} \int_0^T e^{-\alpha t^{\beta}} dt$, which evaluates to

$$p = \frac{\gamma(1/\beta, \alpha(\Delta t_i)^{\beta})}{\alpha^{1/\beta} \beta \, \Delta t_i},$$

where γ is the incomplete gamma function defined by $\gamma(\alpha, x) = \int_0^x e^{-t} t^{\alpha-1} dt$.

3.3 Prediction of the number of collision victims

If the number of wire-strike victims in a period is drawn from a Poisson distribution with parameter λ, then the expectation of this number is λ. Therefore x/p is not only an estimate of λ, but also a prediction (in the statistical sense, or an "estimate") of the number of wire-strike victims since the last patrol, and this is the main interest we have in x/p.

3.4 Estimation of the uncertainty of the predicted number

Assuming the model is right, there are two sources of error in the prediction: (1) uncertainty of the estimates of α and β (needed to find the probability p of finding a wire-strike victim) in the Weibull distribution, and (2) uncertainty of the prediction x/p of the number of victims, even assuming p is given.

To find a measure for the first uncertainty, due to the uncertainty of the estimation of α and β, the following is done: 1000 bootstrap samples of placed birds are drawn, each made by drawing n samples with replacement from the set $\{(t_i, t'_i)\}_{i=1}^{n}$ of observations. From the jth sample, estimates of α and β are obtained as described before, p can be calculated, and a prediction $y_j = x/p$ of the number of victims is obtained, $j=1, 2, \ldots, 1000$. An estimate of the variance of the predictor due to the uncertainty of α and β is thus

$$\frac{1}{999} \sum_{j=1}^{1000} (y_j - \bar{y})^2,$$

where $\bar{y} = \frac{1}{1000} \sum_{j=1}^{1000} y_j$.

Since the α and β estimates are common to the whole experiment, the same set of 1000 bootstrap estimates of α and β can be used for each of the patrols in the experiment.

A measure of the second uncertainty is given by the variance of the conditional distribution of the actual number of victims given the number found. Assuming p is non-stochastic,

$$\left(\frac{1}{p} - 1\right) x$$

can be shown to be an estimate of this variance.

An estimate of the total standard deviation of the predictor is then

$$\sqrt{\frac{1}{999} \sum_{j=1}^{1000} (y_j - \bar{y})^2 + \left(\frac{1}{p} - 1\right) x}.$$

3.5 Prediction for the whole experimental period

As described in the previous two subsections, for each interval between two patrols the number of casualties can be predicted and the uncertainty of the prediction can be estimated. Lets s denote the number of patrols (except the first one, which does not provide any information because nothing is known about when the collisions happened) in an experiment. Denote by z_k the prediction of the number of causalties between the $k-1$st and the kth patrol (letting the first one be no. 0), $k = 1, 2, \ldots, s$. Then a prediction of the number of collision casualties for the whole experimental period is

$$\sum_{k=1}^{s} z_k .$$

Each of the 1000 bootstrap samples also gives an estimate u_j of the total number of casualties, $j = 1, 2, \ldots, 1000$. In the same way as in the previous subsection, we take

$$\sqrt{\frac{1}{999} \sum_{j=1}^{1000} (u_j - \bar{u})^2 + \sum_{k=1}^{s} \left(\frac{1}{p_k} - 1\right) x},$$

as an estimate of the standard deviation of the predictor, where p_k is the probability (given the estimated α and β) that a victim from the kth period is seen.

If the interval between two patrols is longer than the 95% percentile of the Weibull distribution, that is, the probability of a bird colliding at the beginning of the period still being there on the next patrol is less than 0.05, we have chosen to disregard the period in question, so that the predicted number of casualties for the whole experimental period ignores any collisions that might have happened during such periods.

4. Results

4.1 Removal of placed corpses

The results of the part of the experiments that consisted of placing dead birds (Table 2) were used to estimate the parameters α and β of the distribution of the lying time of the corpses, and also to provide an estimate of the expectation value of this distribution (Table 3). A comparison of the removal data for experiments nos. 1 and 2 and the data predicted by the model is shown in Figure 1 (a similar comparison for experiments nos. 3, 4, and 5 could not easily have been done because of the different methodology used in those experiments).

Table 2. Removal data for the experiments. A pair of numbers is given for each bird placed. The first number is the last time (in days) the bird placed was still observed; the second is the first time (in days) it was no longer to be seen. If several birds have the same observations, then the number of such birds is shown before the pair of numbers.

Experiment no.	Number of birds	Observations (see caption)
1	20	(2, 3), 2 (3, 6), 2 (7, 8), 2 (9, 10), 13 (10, ∞)
2	13	5 (1, 3), 4 (3, 6), 2 (6, 7), 2 (7, 10)
3	8	(0, 4), 3 (0, 5), (0, 6), (6, 10), (9, 14), (10, 15)
4	10	2 (0, 5), (0, 6), (0, 8), (5, 10), (5, 11), (10, 12), (10, 15), (22, 27), (24, 29)
5	12	3 (0, 5), 5 (0, 6), 2 (0, 7), (10, 16), (16, 22)

Table 3. Estimates of the Weibull distribution parameters.

Experiment no.	α estimate ($day^{-\beta}$)	β estimate	Estimated expected lying time (days)	95% percentile of Weibull distribution (days)
1	0.0032	2.13	13.2	25.0
2	0.035	2.08	4.4	8.5
3	0.14	1.16	5.3	14.4
4	0.066	1.15	10.1	27.4
5	0.67	0.53	3.8	16.7

The results show that even a large bird such as the Willow Ptarmigan was removed rather fast by scavengers. There were, however, seasonal differences. The midwinter experiments (nos. 1 and 4), with severe cold, snow and a rather low scavenger activity, indicate that corpses remain untouched for a longer period than in the spring or autumn (see *Estimated expected lying time* in Table 3), when the scavenger activity is more intense.

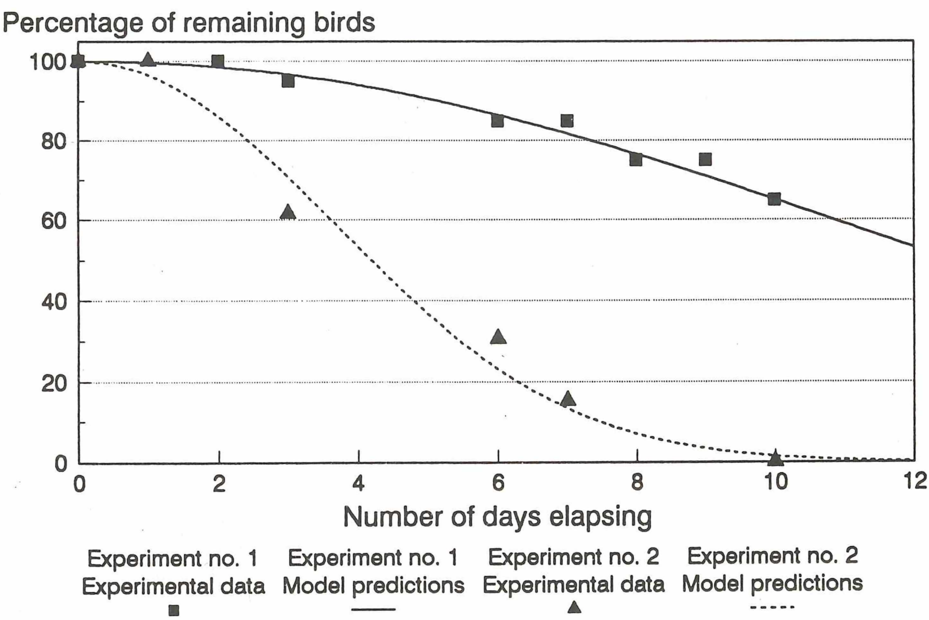

Figure 1. Comparison of removal data for experiments 1 and 2 and the data predicted by the model.

In experiment no. 1 (January), some footprints associated with faeces remains indicated that the Red Fox *(Vulpes vulpes)* and the Raven *(Corvus corax)* were the two most important scavengers (at least two certain cases of both were recorded). In experiment no. 2 (March), the Red Fox, the Pine Marten *(Martes martes),* and especially scavenging birds (mostly the Raven and the Hooded Crow *(Corvus corone cornix)* seemed to have been the most frequent scavengers (footprints and excrement). In the second experiment set (experiments nos. 3, 4 and 5), the most important scavenging species was the Red Fox, tracks of which could be seen during the whole experiment period. Also two Golden Eagles *(Aquila chrysaëtos)* (probably a pair) stayed in the valley the whole winter and one of the Golden Eagles was actually observed taking one of the experiment objects. Tracks of the Stoat *(Mustela erminea)* were also observed several times at spots where birds had been placed. The Common Shrew *(Sorex araneus)* was also observed to eat remains of placed birds. Altogether the corvids played a less important scavenging role in this mountain area, but Ravens were observed in the vicinity of the power lines a couple of times.

4.2 Patrols for wire-strike victims

The numbers of wire-strike victims found during patrols are probably less than the true numbers of victims, due to corpse removal by scavengers. Predictions (estimates) of these true numbers were obtained by utilizing the removal data of the placed corpses as described in Section 3. The details are shown in Tables 4 and 5 for experiments nos. 1 and 2, respectively, and a summary for all the experiments is in Table 6.

Table 4. Number of wire-strike victims found and estimated actual number of victims in experiment no. 1. All corpses were removed on November 8 1984, and the first ordinary patrol was made on December 3, which is the first entry in the table. The predictions and uncertainties in the table are explained in *The model.* An asterisk in the table denotes that the corresponding period is disregarded due to its length *(see The model).*

Days since last patrol	Number of corpses found	Probability *(p)* of finding corpse	Predicted number of corpses found
25	0	0.52	*
2	3	1.00	3.0 ± 0.1
29	2	0.45	*
4	0	0.98	0.0 ± 0.0
9	0	0.90	0.0 ± 0.0
2	1	1.00	1.0 ± 0.1
11	0	0.86	0.0 ± 0.0
2	0	1.00	0.0 ± 0.0
25	0	0.52	*
2	0	1.00	0.0 ± 0.0

Table 5. Number of wire-strike victims found and estimated actual number of victims in experiment no. 2. All corpses were removed on February 27 1985, and the first ordinary patrol was made on March 13, which is the first entry in the table. The predictions and uncertainties in the table are explained in *The model.* An asterisk in the table denotes that the corresponding period is disregarded due to its length (see *The model*).

Days since last patrol	Number of corpses found	Probability (p) of finding corpse	Predicted number of corpses found
14	1	0.32	*
12	1	0.37	*
2	0	0.95	0.0 ± 0.0
14	1	0.32	*
6	2	0.68	3.0 ± 1.2
13	0	0.34	*
2	0	0..95	0.0 ± 0.0
2	2	0.95	2.1 ± 0.3
3	1	0.90	1.1 ± 0.4
2	2	0.95	2.1 ± 0.3
2	1	0.95	1.0 ± 0.2
3	0	0.90	0.0 ± 0.0
2	0	0.95	0.0 ± 0.0
8	0	0.54	0.0 ± 0.0
4	1	0.83	1.2 ± 0.5
2	0	0.95	0.0 ± 0.0
2	0	0.95	0.0 ± 0.0

Table 6. Summary of patrols. *"Short" periods* are periods that are shorter than the 95% percentile of the Weibull distribution of the experiment (see *The model* and Table 3).

Ex-peri-ment no.	All periods			"Short" periods			
	No. of patrols	Dura-tion (days)	No. of corpses found	No. of patrols	Dura-tion (days)	No. of corpses found	Predicted no. of corpses found
1	10	110	6	7	32	4	4.0 ± 0.1
2	17	93	12	13	40	9	10.5 ± 1.4
3	10	51	3	10	51	3	4.2 ± 2.1
4	19	95	3	19	95	3	3.6 ± 1.0
5	9	51	10	9	51	10	27.9 ± 17.4

5. Discussion

Although some authors have experienced scavengers as a minor source of bias when total wire-strike losses are calculated (e.g., Rusz et al. 1986) and others have found the problem to vary greatly between adjacent localities (e.g., Meyer 1978; Faanes 1987), most removal experiments show a rather fast turnover which should be compensated for (Hoerschelmann, Haack & Wohlgemuth 1988). In our opinion, the proposed model is a useful tool for making these types of estimates more reliable. The most precise estimates of numbers of wire-strike casualties are achived when the conditions when placing corpses are similar to the conditions when patrolling. Overall, it seems important to estimate the "local removal rate" through these types of experiments when patrols are made in order to obtain estimates of small game losses through collisions. As the removal rate obviously varies through the year and also between years, the removal rate parameters α and β should be estimated according to the specific research area and time. In long-term patrolling for collision victims it is possible to combine the recording with removal experiments, as was done in the Southern Norwegian experiments, thus reducing the experimental costs at the same time as more precise estimates of the removal rate parameters are obtained.

Another advantage in performing the removal experiments and patrol simultaneously is the possibility for spreading the placing of corpses. The artifically low spacing of corpses during the Central Norwegian experiments obviously creates an interpretation problem. The density of corpses was far greater than was ever found during the patrols. The chance of finding the "neighbouring birds" may not be the same as the chance of finding the first bird. When estimating the removal rate parameters α and β, the assumption that the removal of one bird is independent of the removal of another is made. If the removal rate parameters are estimated on the basis of very closely spaced baits, as in the Central Norwegian experiments, and assuming that neighbouring birds to those scavenged have a greater chance of being discovered than more distant birds, the estimated removal rate will be too high. The collision rate prediction will accordingly be too high.

On the other hand, scavengers, such as the Red Fox, may be shy of baits. This factor biases the estimate of removal rate parameters in the opposite direction so that the observed turnover may be less than under natural conditions, and this contributes to making the collision rate prediction low. Red Fox footprints were sometimes observed close to an untouched corpse, especially the first and second night after a bird was placed (Central Norway). However, on the third night (or later), the Red Fox took the bird and removed it, not eating it on the spot. Generally there were some difficulties in determining the predator species by the presence of footprints because of the snow conditions in the experiment areas (either very hard due to the wind or very loose). In some cases in Central Norway both the Raven and the Hooded Crow were seen sitting near the bird corpses.

An interesting question, which should be investigated, is whether wire-strike victims in these experiment areas with a generally sparse bird fauna during the winter can support a higher population of scavenging and predatory species than the area would otherwise be able to feed. A Capercaille of about 5 kg represents an important piece of food under midwinter conditions for any of the scavenging species present in the Central Norwegian experiment area.

A House Sparrow removal experiment beneath a power line with control some distance away (SCOTT et al. 1972) showed a slower turnover for the control birds, i.e. the scavengers concentrated their searching activities on areas with optimum food conditions (cf. CROZE 1970). Experiments using Starlings (HEIJNIS 1980) showed a similarly rapid turnover as 74% of the birds were removed within 24 hours, which was a turnover 4-5 times that observed outside the power-line corridor.

In Norway it es commonly claimed — especially by hunters — that the Red Fox patrols beneath overhead transmission and telegraph lines in order to find bird corpses. During our investigations, tracks of the Red Fox were observed continuously and regularly for several kilometres along some of the power-lines sections, especially during the Southern Norwegian patrols.

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References

BEAULAURIER, D. L. (1981): Mitigation of bird collision with transmission lines. Bonneville Power Administration, Portland Oregon. — BEVANGER, K. (1988): Skogsfugl og kollisjoner med kraftledninger i midt-norsk skogsterreng. Økoforsk rapport 9: 1-53. — BEVANGER, K. (1990): Rypekollisjoner mot kraftledninger i Hemsedal. NINA oppdragsmelding 49: 1-15. — BEVANGER, K. & O. SANDAKER (1993): Kraftledninger som mortalitetsfaktor for rype i Hemsedal. NINA oppdragsmelding 193: 1-25. — CROZE, H. (1970): Searching Image in Carrion Crows. Paul Parey, Berlin. — DOBINSON, H. M. & A. J. RICHARDS (1964): The effects of the severe winter of 1962/63 on birds in Britain. British Birds 57: 373-434. — FAANES, C. A. (1987): Bird behaviour and mortality in relation to power lines in prairie habitats. Fish Wildl. Tech. Rep. 7, U.S. Fish Wildl. Serv., 24 pp. — HEIJNIS, R. (1980): Vogeltod durch Drahtanflüge bei Hochspannungsleitungen. Ökol. Vögel 2, Sonderheft: 111-129. — HOERSCHELMANN, H., A. HAACK & F. WOHLGEMUTH (1988): Verluste und Verhalten von Vögeln an einer 380 kV Freileitung. Ökol. Vögel 10: 85-103. — KALBFLEISCH, J. D. & R. L. PRENTICE (1980): The statistical analysis of failure time data. John Wiley and Sons, Oxford. — KENDALL, M., A. STUART & J. K. ORD (1987): Kendall's Advanced theory of statistics — 5th ed.Vol. 1: Distribution theory. Exercise 5.20. Charles Griffin & Co. Ltd., London. — LONGRIDGE, M. W. (1986): The impacts of transmission lines on bird flight behaviour. ESCOM Report: 1-279. — MEYER, J. R. (1978): Effects of transmission lines on bird flight behaviour and collision mortality. Prepared for Bonneville Power Administration by the Western Interstate Commission for Higher Education. Bonneville Power Administration, Portland, Oregon. — PUTMAN, R. J. (1983): Carrion and Dung: The Decomposition of Animal Wastes. Edward Arnold, London. — RUSZ, P. J., H. H. PRINCE, R. D. RUSZ & G. A. DAWSON (1986): Bird collision with transmission lines near a power plant cooling pond. Wild. Soc. Bull. 14: 441-444. — SCOTT, R. E., L. J. ROBERTS & C. J. CADBURY (1972): Bird deaths from power lines at Dungeness. British Birds 65: 273-286.

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