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Estimates and Population Consequences of Tetraonid Mortality Caused by Collisions with High Tension Power Lines in Norway

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The Journal of Applied Ecology, Vol. 32, No. 4 (Nov., 1995), 745-753.

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Journal of Applied Ecology 1995, **32**, 745–753

Estimates and population consequences of tetraonid mortality caused by collisions with high tension power lines in Norway

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Summary

1. Capercaillie, black grouse and willow ptarmigan mortality resulting from collisions with high tension power lines (11–420 kV) was estimated, based on the number of casualties found per kilometre of power line patrolled in three boreal forest and low alpine areas.

2. The length (km) of high tension power lines crossing tetraonid habitats was estimated using Geographical Information Systems and general knowledge about species-specific habitats. Of the entire Norwegian high tension power-line grid system (about 95 000 km), 55% was estimated to cross capercaillie habitats, 56% black grouse habitats and 16% willow ptarmigan habitats.

3. Because of biasing factors related to data-collecting procedures, the number of collision victims found per kilometre of power line patrolled was increased by a factor varying from 6·0 to 14·9. The estimated losses were about 20 000, 26 000 and 50 000 for capercaillie, black grouse and willow ptarmigan, respectively, which are about 90%, 47% and 9% of the annual hunting harvest of these species.

4. It was concluded that this estimating procedure may be useful to wildlife management authorities to assess losses caused by overhead wires in general. Locally, this mortality factor should be carefully recorded and considered together with other mortality factors like hunting, to avoid overexploitation.

Key-words: black grouse, capercaillie, collisions, game birds, mortality, power lines, willow ptarmigan.

Journal of Applied Ecology (1995) **32**, 745–753

Introduction

Several studies have been carried out on the incidence of bird collisions with power lines and particularly the proportion of birds killed (Meyer 1978; James & Haak 1979; Beaulaurier 1981; Willdan Associates 1982; Longridge 1986; Faanes 1987). Regional or national estimates of losses, however, have rarely been made (Braaksma 1966; Andersen-Harild & Bloch 1973; Rennsen *et al.* 1975; Gylstorff 1979; Hoerschelmann, Haack & Wohlgemuth 1988). Investigations have mainly taken the form of 'worst case studies', and quantitative estimates have neither singled out species or groups of species, nor differentiated between resident species and migrants.

Current research on resident tetraonid species colliding with power lines in boreal habitats in Norway (Bevanger 1988, 1993a,b,c; Bevanger & Sandaker 1993) has shown this to be a regular source of mortality for willow ptarmigan (*Lagopus lagopus* L.), capercaillie (*Tetrao urogallus* L.) and black grouse (*Tetrao tetrix* L.), the three most popular small-game species in Norway. The estimated harvest of small game for the whole country — average per year for the period 1987/88–1991/92 — was 572 000 ptarmigan (*Lagopus* spp.), 55 500 black grouse and 22 200 capercaillie (CBS 1993).

There is a growing interest on the part of wildlife management authorities and the hunting fraternity in the comparative importance of hunting and wire-strike mortality among small-game populations (e.g. Nordmøre herredsrett 1988; Frostating lagmannsrett 1989; Bevanger 1993c). Although it is commonly claimed among hunters and landowners that there has been a significant decline in gamebird populations in Norway during this century, this allegation still remains an open question. It is also of interest to map additional mortality factors in order to judge their significance for sustainable harvest and management of the game bird populations (e.g. Baines & Lindén 1991; Kastdalen 1992).

Small-game hunting is economically important to local communities (Steen 1989) and the question of hunting bags being lost through power lines crossing small-game hunting areas has been repeatedly raised in recent years (e.g. Thompson 1978; Gylstorff 1979; Hobbs 1987), especially by landowners. An owner may obtain higher rent for hunting rights in an area reputed to be optimal partly because no power lines cross it (Nordmøre herredsrett 1988). Norwegian courts have ruled that power lines kill tetraonid game birds, but there is disagreement on whether power companies should be required to reimburse financial losses (Nordmøre herredsrett 1988; Frostating lagmannsrett 1989).

The objectives of this paper are (i) to propose a procedure for estimating losses of tetraonids through collisions with high tension power lines in Norway, and (ii) to estimate these losses. Particular attention is paid to certain biasing factors connected with procedures for obtaining quantitative estimates in boreal habitats, and how this non-hunting mortality may influence population performance.

Material and methods

The data were derived from a single study in boreal forest habitats in central Norway, concerning capercaillie and black grouse mortality, and two studies dealing with willow ptarmigan mortality in northern boreal birch forest and alpine areas in northern and southern Norway. During these studies, sections of 11 power lines carrying tensions between 22 and 300 kV were searched annually for dead birds (Bevanger 1988, 1993a,b; Bevanger & Sandaker 1993).

The finding frequency (*FF*), i.e. the number of victims found per kilometre of power line patrolled, were the basic data for the loss estimates (Bevanger 1993b). These studies showed statistically significant seasonal differences in wire-strike mortality (Bevanger 1993b). Being season-specific, the finding frequency allows the number of victims each season to be calculated, which is necessary if inferences on populations are to be made.

By the end of 1991, the high tension power-line grid system (11–420 kV, i.e. mainly the secondary distribution system and the transmission system) amounted to 94 214 km of a total length of 215 203 km (CBS 1993), i.e. 44%. An ARC/Info program (ESRI 1992) was used to obtain data on the proportion of these power lines crossing willow ptarmigan, capercaillie and black grouse habitats.

A vegetation map, a contour map, a national map depicting county divisions and a map showing power lines, formed the basis for the estimates. The vegetation map was a digitized version of the National Atlas of Norway (1:1 000 000) published by the Norwegian Mapping Authority (NMA) and depicting Norwegian vegetation regions (Table 1) (Dahl *et al.* 1986). The two maps containing information on altitude and counties were A-generalizations (i.e. digitized versions of 1:1 000 000 maps published by NMA). The map showing digitized data of the Norwegian high tension power-line grid system was provided by the Defence Mapping Agency. Unfortunately, these data had not been digitized for the northern part of the country, or for three counties in south-eastern Norway (Fig. 1).

The ARC/Info program was used to construct a map on which the smallest unit was an area with an unique combination of vegetation, elevation and county. This contained about 50 000 small area units. The power-line map was superimposed on this map dividing the power-line grid system into small sections, each of which derived information from the area map. This procedure enabled a data file to be created, the smallest unit of which is a section of power lines with information on length, vegetation, altitude and county. On the basis of this file, SPSS (SPSS Inc. 1992) was used for various statistical measures of length and area.

General knowledge of the distributional pattern and habitat requirements of the three tetraonid species (Haftorn 1971) was used for habitat definitions and fitted to areas below 300, 600, 900 and 1200 m a.s.l., respectively, as the digitized map only permitted distinction of these elevations.

A simple extrapolating procedure was used for those counties where information on power-line distribution was inadequate. The species-specific habitat areas were calculated using the same criteria as before (Table 1). The length of power lines within the species-specific habitats was estimated by assuming that the ratio of the species-specific habitat area to the power-line length within this habitat is equal to the ratio of the total area of the county to the total power-line length in the county.

Estimates of (national) losses were based on the number of bird victims found beneath the power line during organized inspections (patrols) (Bevanger 1993a,b; Bevanger & Sandaker 1993). The mortality for each species and season equals the bias-adjusted finding frequency (AFF) multiplied by the lengths of power line (km) crossing the habitat of the species (Tables 2 and 3). The four biasing factors considered are search, habitat, crippling and scavenger biases (Table 2) (Meyer 1978; James & Haak 1979; Beaulaurier 1981; Willdan Associates 1982; Faanes 1987; Hartman *et al.* 1992).

Search bias

James & Haak (1979) distinguished between the recovery rate of 'large' and 'small' birds (difference not defined), large birds giving a recovery rate between 67% and 80%, while Beaulaurier (1981) reported recovery rates of 78% and 82%.

The proportion of winter victims found when snow thaws in spring is difficult to assess, but seems to remain between 50 and 70% according to experience from northern Norway (K. Bevanger, unpublished) where experiments were made to obtain information about the proportion of winter victims that can be expected to be found (and categorized as reindeer fence collision victims) during patrols along reindeer fences immediately after the snow thaws. The bias caused by the snow cover may also be significant for obscuring the period when collision took place when patrols cover a one year cycle.

Thus, the search biases for capercaillie and black grouse were considered to be equal; 20%, 40% and 20% for autumn (September–October), winter (November–March) and spring (April–May), respectively, and the winter bias for willow ptarmigan was raised to 60%. The detectability

Table 1. Criteria used to select high tension power-line sections in capercaillie, black grouse and willow ptarmigan habitats, and estimated regional lengths of power lines. General knowledge about distribution and habitat requirements (Haftorn 1971) were used and correlated to the units used by Dahl *et al.* (1986) in the National Atlas for Norway. The vertical extension (m a.s.l.) of the tetraonid habitats is given for each part of the country. Nordland, Troms and Finnmark are the three counties of northern Norway. N, nemoral; BN, boreonemoral; SB, southern boreal; MB, middle boreal; MNB, middle and northern boreal; NB, northern boreal; LA, low alpine; CL, coastal section lowland belt; CP, coastal section prealpine belt; CA, coastal section alpine belt. * In Northern Norway (Nordland, Troms and Finnmark), different criteria are used for different counties regarding capercaillie habitats. There are no black grouse in Finnmark

Geographical and vegetation region Power line length	Capercaillie	Black grouse	Willow ptarmigan
Southern Norway			
Vertical extention	0–900	0–900	900–1200
Vegetation regions	N,BN,SB,MB,NB	N,BN, SB,MB,NB	NB,LA
Power line length (km)	27 941	27 941	1420
Central Norway			
Vertical extention	0–900	0–900	0–1200
Vegetation regions	SB,MB,NB	CL,CP,SB,MB,NB	CL,NB,LA
Power line length (km)	13 197	14 950	4140
Western Norway			
Vertical extention	0–600	0–900	300–900
Vegetation regions	CL,MNB	CL,CP,MNB,NB	CA,MNB,NB
Power line length (km)	4672	5291	1747
Northern Norway*			
Vertical extention	0–600	0–600	0–600
Vegetation regions	MB,NB	MB,NB	CL,MB,NB,LA
Power line length (km)	5903	4563	7263
Nordland, Troms			
Vertical extention	0–600	0–600	0–600
Vegetation regions	MB,NB	MB,NB	CL,MB,NB,LA
Power line length (km)	4563	4563	–
Finnmark			
Vertical extention	0–300	lacking	0–600
Vegetation regions	MB,NB	–	CL,MB,NB,LA
Power line length (km)	1340	–	–

of birds varies according to their size and colour. In winter, ptarmigan are particularly difficult to find owing to their white plumage, the black and brown feathers of the capercaillie and black grouse being more easily seen, provided the birds are not completely snow covered.

Scavenger removal

Based on removal rate experiments using willow ptarmigan, mathematical models have been devised for the number of birds striking the wires per unit of time and for the removal rate of the dead birds (Bevanger, Bakke & Engen 1994). The experiments demonstrated seasonal variation in the removal rate, the rate increasing from midwinter to spring. In the period from March to May, few artificial victims were left untouched for more than 2–3 days, several being removed during the first 24 hours. The models were designed to improve the accuracy of quantitative estimates on a local scale.

Due to the observed turnover rate and the gap between the searching patrols, the corrections chosen for black grouse and capercaillie were 70%, 50% and 70% for autumn, winter and spring respectively, and for willow ptarmigan 80%, 70% and 80% for the same seasons. 'Small' birds like willow ptarmigan can be expected to have a faster turnover than larger ones like capercaillie, which are not easily removed by scavengers without leaving feathers.

Habitat bias

Systematic measurements to test habitat bias were not made for the power-line corridors in the present study. It was estimated (subjective judgements for different seasons and sections of power line), that 10–30% of the corridors were impossible to search or difficult to search effectively, values being particularly high in central and southern Norway. All three species were judged to have the same bias — 20%, 30% and 20% in autumn, winter and spring, respectively.

Crippling bias

In a German study (Heijnis 1980), wounded, radio-tagged

Fig. 1. Digitized data for the geographical distribution of high tension power lines (11–420 kV) in Norway. There are insufficient data for the three northernmost counties, Nordland, Troms and Finnmark and the three counties in the south-east — Vestfold, Østfold and Akershus. Data provided by the Defence Mapping Agency.

Table 2. Seasonal and species-specific corrections (% missed during the field work) for estimates of Norwegian tetraonid mortality due to collisions with high tension power lines. The correction figures described in the text (*pbf*, *pnr*, *ps* and *pbk*) are 1 minus these figures divided by 100. A, autumn (September–October); W, winter (November–March); S, spring (April–May). 'Total' denotes the cumulative correction multiplied by the total number of collision victims found (*tdb*). See text for estimating procedure

	Correcting factors														
	Search bias			Scavenger removal			Habitat bias			Crippling bias			Total		
Species	A	W	S	A	W	S	A	W	S	A	W	S	A	W	S
Capercaillie	20	40	20	70	50	70	30	20	30	20	30	20	7·4*tdb*	6·0*tdb*	7·4*tdb*
Black grouse	20	40	20	70	50	70	30	20	30	20	30	20	7·4*tdb*	6·0*tdb*	7·4*tdb*
Willow ptarmigan	20	60	20	80	70	80	30	20	30	20	30	20	11·2*tdb*	14·9*tdb*	11·2*tdb*

birds were traced as far as 2 km from the collision spot. In a Dutch and a Finnish study the crippling biases were judged as 50% and 22%, respectively (Renssen *et al.* 1975; Hiltunen 1953).

Several observations during the field work suggested this to be a significant biasing factor. The pointing bird sometimes find fatally injured birds which had managed to leave the clear-felled corridor before dying, sometimes far beyond the corridor (Bevanger 1993a,b; Bevanger & Sandaker 1993). The bias was considered equal for the three species; 20%, 30% and 20% in autumn, winter and spring, respectively.

Table 3. Estimates of total tetraonid losses due to collisions with power lines in Norway. No summer (June–August) mortality was recorded. *FF*, finding frequency, i.e. the seasonal-specific number of collision victims found per km of power line searched; *AFF*, adjusted finding frequency, i.e. *FF* corrected with respect to search, scavenger removal, habitat and crippling bias (cf. Table 2); A, autumn (September–October); W, winter (November–March); S, spring (April–May). The power line length (km) is related to species-specific, potential habitats (Table 1) and 11–420 kV categories. The *FF* values are based on Bevanger (1993b)

	FF			*AFF*				Estimated, seasonal losses (number. of birds)		
Species	A	W	S	A	W	S	Power lines (km)	A	W	S
Capercaillie	0·012	0·032	0·014	0·089	0·192	0·104	51 713	4600	9900	5400
Black grouse	0·035	0·022	0·014	0·259	0·132	0·104	52 745	13 700	7000	5500
Willow ptarmigan	0·025	0176	0·043	0·280	2·622	0·482	14 570	4100	38 800	7000

on a combination of data obtained during the present investigation and information from the literature. However, they are necessarily subjective and some must be regarded as qualified guesses.

The calculating procedure for the bias corrections is similar to that used by Meyer (1978) and James & Haak (1979). Let N denote the total number of collision victims along a patrolled power-line section, and $1 - pbk$ the proportion of these that are undetected because of the crippling bias (pbk = 'percentage of birds colliding that were killed and fell on the search area' (Meyer 1978)). Let $1 - ps$ denote the proportion of the remaining $pbk \cdot N$ victims that are undetected because of the habitat bias (ps = 'proportion of line section which is searchable' (James & Haak 1979)). Further, let $1 - pnr$ denote the proportion of the remaining $ps \cdot pbk \cdot N$ victims that are undetected because of the scavenger bias (pnr = 'percentage of dead birds not removed by scavengers — derived from removal rate study' (Meyer 1978)), and finally, let $1 - pbf$ denote the proportion of the remaining $pnr \cdot ps \cdot pbk \cdot N$ victims that are undetected because of the search bias (pbf = 'percentage of dead birds found based on dead bird plant study' (Meyer 1978)).

Thus, the total number of dead birds, $tdb = pbf \cdot pnr \cdot ps \cdot pbk \cdot N$ bird victims are detected, and the total loss N may be estimated by $tdb/(pbf \cdot pnr \cdot ps \cdot pbk)$. Using the autumn corrections for capercaillie as an example (Table 2), the estimate $tdb/(0{\cdot}8 \cdot 0{\cdot}3 \cdot 0{\cdot}7 \cdot 0{\cdot}8) = tdb/0{\cdot}13$ is obtained for the total loss. Using the *FF* values for capercaillie in autumn, i.e. the autumn number of capercaillie collision victims found per km of power line searched, this means that the adjusted finding frequency, $AFF = 7{\cdot}4 \cdot FF$.

Results

It was estimated that about 55% (51 700 km) and 56% (52 700 km), respectively, of the high tension power-line grid system cross capercaillie and black grouse habitats and about 16% (14 600 km) transects willow ptarmigan habitats (Table 1).

The bias estimates increased the autumn and spring finding frequencies with a factor of 7·4 and the winter finding frequency with a factor of 6·0 considering the capercaillie and black grouse. The finding frequencies of the willow ptarmigan were increased with a factor of 11·1 in autumn and spring, and 14·9 in winter (Table 2).

For all species, there were considerable seasonal differences for the estimated losses. Capercaillie and willow ptarmigan losses peaked in winter, and losses in spring slightly exceeded those in autumn (Table 3). Black grouse losses showed a different pattern, with an autumn peak and a decrease towards spring (Fig. 2).

The estimated total, annual loss of about 20 000 capercaillie was about 90% of the yearly hunting harvest, while corresponding figures for black grouse (26 000) and willow ptarmigan (50 000) were about 47% and 9%, respectively.

To see how changes in the bias corrections affected the outcome, a simple sensitivity analysis was made, using the estimated winter losses for willow ptarmigan (38 800 birds; Table 3) as an example. If the winter values for each of the four biasing factors are raised by 10% the winter losses will be estimated as 101 800, i.e. a 162% increase. If the winter values for each of the four biasing factors are reduced by 10% the estimated winter losses will be 17 800, i.e. a 54% reduction. If the winter values of one of the biasing factors, e.g. scavenger removal, are

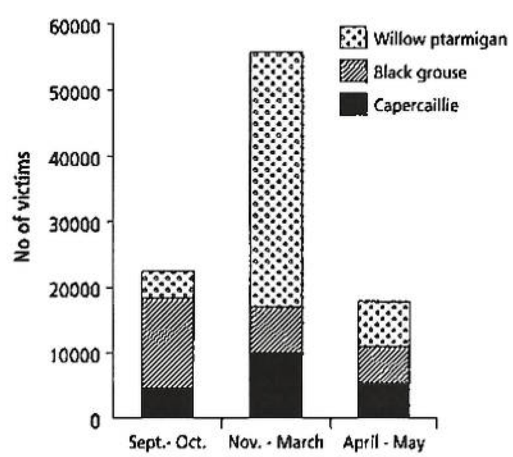

Fig. 2. Estimated seasonal losses for capercaillie, black grouse and willow ptarmigan due to collisions with high tension power lines in Norway.

increased/reduced by 10%, the estimated losses will be about 57 200/28 600, i.e. an increase/reduction of 47 and 26%, respectively.

Discussion

QUANTITATIVE ESTIMATES

Quantitative estimates at a national level, for obvious reasons, have to be at an order of magnitude, which may reduce the practical significance of the data. Moreover, national losses are of less interest for management than regional or local estimates. However, the method used in the present study may prove useful on a local level. County wildlife management authorities are improving their information on local natural resources. Power lines and other types of overhead wires, together with wildlife areas, are being increasingly mapped (Sørensen & Reitan 1990) and made available in digitized form.

A confident minimum estimate can be obtained using the number of victims (including feather spots) found during searches for dead birds (*FF*). Estimates may be improved in several ways, although the collision problem is not identical in different habitats or for different species. Correction tests must be designed and fitted to local conditions and target species. Knowledge of species-specific behavioural and ecological characteristics is particularly important, as are the making of estimates and correction factors in different seasons.

The accuracy of the lengths of power lines estimated to cross tetraonid habitats would be improved if more detailed maps of vegetation types were available, allowing more precise definition of species-specific habitats, for instance selecting different types of forest, agricultural areas, etc. A more precise estimate would also be obtained if more specific data for altitude intervals were available.

A relationship between the number of birds in an area and the probability that collisions will occur seems evident (Anderson 1978; Faanes 1987). Quantitative estimates are commonly based on the number of collisions observed for a known number of birds observed crossing a specific power-line section (e.g. Meyer 1978; James & Haak 1979; Beaulaurier 1981; Willdan Associates 1982; Faanes 1987; Hartman, Byrne & Dedon 1992). This procedure, however, cannot be adopted in tetraonid habitats as information on bird crossings are not available due to low bird abundance, e.g. it has been estimated that there are 7·5 capercaillie and 4 black grouse per km² in central Norway in the autumn (Myrberget 1984), and a breeding density of approximately 2·5 birds per km² in southern Norway (Wegge *et al.* 1990).

In boreal ecosystems in Fennoscandia, long-term and short-term oscillations in populations of tetraonids (e.g. Angelstam, Lindström & Widén 1985; Lindén 1988) probably affect the number of collisions and victims recorded. Although present estimates are based upon average collision figures over a 3-year cycle, they may be influenced by this cyclicity. However, the weakest and most controversial points in the 'estimating chain' are obviously to be found among biasing factors related to field data sampling methods.

BIAS CORRECTIONS

Variation in local conditions (geographical, topographical, meteorological, technical and faunistic) (Bevanger 1993b, 1994) makes it difficult to obtain suitable data to adjust the biasing factors correctly, which tends to result in speculative quantitative estimates. As additional data on tetraonid mortality caused by power lines are lacking for the boreal region and information on biasing factors is limited, a 'qualified guess' has to be applied. However, it will scarcely be practical to predict specific correcting factors to estimate national losses. Quantitative estimates may be improved on a local scale through separate experiments of each factor. Radio-tagging a large proportion of a population would probably give particularly valuable information.

Search bias

Several authors have calculated the number of victims not found during the searches using observer error experiments. Few authors, however, have published the basic data from their experiments, e.g. the time of year when they were carried out or the specific seasonal conditions. Because of the snow cover, in Fennoscandia lasting from November through April/May, the search bias in this period is partly replaced by a 'snow cover bias', as snow and wind may make collision victims invisible within minutes (Bevanger 1993b). Since snow conditions change both seasonally and daily, traditional bias experiments are not an appropriate tool. Although no search bias experiments were carried out, pointing dogs used during the patrols minimized the impact of the search, as well as the habitat bias.

Scavenger removal

Highly nutritious organic matter is never left untouched for long (Putman 1983). Moreover, scavenging activity changes during a 24-hour period, being generally high at night and in the early morning due to the nocturnal and crepuscular behaviour of several abundant scavenging mammals. The exact timing of the searches and the time elapsing between two patrols may therefore significantly affect the *FF* values. The size of the victims and the scavenger species present are also crucial factors for the removal pattern and the probability that the patroller will discover remains of collision victims or other evidence which may lead to the conclusion that a collision has taken place.

Experiments to determine removal rates have been performed in several studies (Dobinson & Richards 1964; Scott, Roberts & Cadbury 1972; Meyer 1978; James & Haak 1979; Heijnis 1980; Beaulaurier 1981; Willdan Associates 1982; Longridge 1986; Faanes 1987; Hoerschelman, Haack & Wohlgemuth 1988; Hartman, Byrne & Dedon 1992). Removal experiments were also made in the Norwegian studies (Bevanger 1988, 1990a, 1993a,b). As patrols for forest grouse in these investigations only took place every 2–3 weeks and for willow ptarmigan every 5–7 days, great uncertainty obviously attaches to the proportion of casualties falling into the clear-felled corridor that was patrolled. This was also evident from the estimated uncertainty in the predicted number of casualties in a model (Bevanger, Bakke & Engen 1994).

Habitat bias

Habitats crossed by power lines differ with respect to how easy they are to search. This bias varies with the season, conditions being most difficult during the growth period in summer. At the end of November, snow and wind smooth out the landscape, covering shrubs and short vegetation and filling in small depressions. Although most collisions take place in winter and spring, some occur in autumn and late spring when there is no snow. Moreover, even when snow is present, vegetation may still prevent efficient search in some forest habitats.

Crippling bias

Some birds sustain injuries which are not immediately fatal during wire strikes, allowing them to continue flying for some distance. Some authors point out that 'most birds' striking power lines fly off, eventually to die or recover (Willard 1978). The bias also varies with the season: poor light conditions in winter at high latitudes are thought to increase the collision hazard (Bevanger 1993b) and the crippling rate may also be higher. Estimates of a crippling bias require direct observation of collisions and of the number of birds falling or continuing beyond the power-line corridor. It is impossible to find out the survival percentage for those continuing unless experiments are conducted using radio-tagged birds.

POPULATION ASPECTS

Game-bird populations have been supposed not to be significantly disturbed by mortality caused by interaction with utility structures, and much less than by recreational hunting (Hobbs 1987). The present estimates of tetraonid losses because of collisions with high tension power lines are interesting, particularly regarding the capercaillie and black grouse, the willow grouse figures being more insignificant. Assuming that the capercaillie losses are correct, it may be relevant to compare the mortality due to power lines with the hunting harvest. If the bias corrections accidentally should be estimated too low, the sensitivity test demonstrates that only a small increase will raise the casualty number notably.

Locally, the losses due to power lines may exceed the hunting bag. In southern Norway (Bevanger 1993c), the proportion of willow ptarmigan recorded as victims of collisions with power lines was found to be 60% of the combined hunting and estimated wire-strike mortality. Although that figure was reached because of a specific local hunting effort and efficiency, it illustrates that local collision mortality may be substantial.

The effect of hunting on tetraonid populations has been given increased attention in recent years (Ellison 1991; Kastdalen 1992), the crucial question being whether hunting mortality is compensated for or is additive. In general, there seem to be indications of limited compensation for hunting mortality among most tetraonids (Bergerud 1985).

Few data are available in Norway on the proportion of tetraonid populations harvested during the hunting season. In 1923–39, 549 willow ptarmigan were banded in the Øyer area of southern Norway. On average, 55% of the birds were shot or caught in the hunting season during the same period (minimum in 1939 with 27·3% and maximum in 1928 with 81·0%) (Olstad 1953). An investigation in southern Norway in 1987–89 (Kastdalen 1992) revealed that 7% of the stock prior to hunting was taken in one area and 54% in another. Less than 15% of the censused population of capercaillie and black grouse was shot during the hunting season.

This indicates substantial local variations with respect to the expected effect of hunting activity on populations. It also underlines that assessing mean values of the national bag for a certain species may merely camouflage local overexploitation of a resource. Estimates of national losses through collisions with power lines may camouflage significant local losses as well.

The seasonal and species-specific pattern regarding the estimated power-line induced mortality, follow a similar pattern as natural mortality. For black grouse in Sweden, natural mortality is found to peak in autumn (Angelstam 1984) and a peak in natural mortality for capercaillie during winter is found in southern Norway (Wegge *et al.* 1990). With respect to the willow ptarmigan, the winter mortality is also known to be most significant, (Hudson 1992). However, tetraonid mortality caused by power lines has its own peculiarities. In Norway, most hunting of tetraonids takes place during a couple of months in autumn (September and October) when weather conditions are still favourable; in southern Norway, the willow ptarmigan hunters actually finished 53% of their total hunting activity during the first 7 days of the hunting season (Kastdalen 1992). The collision mortality for willow ptarmigan and capercaillie peaks during winter and early spring (Fig. 2) (Bevanger 1993b). Thus, there is an increased probability that the victims are birds which would have reproduced. These two types of 'harvesting' therefore have different built-in population consequences.

Birds in the vicinity of a power line run a greater risk of becoming collision victims than an 'average' bird. A power line close to a capercaillie lek may be expected to reduce the local capercaillie density or at least create a short-term decrease. Hunting activity is usually distributed over a larger area. The impact area, i.e. the area in which power lines have a behavioural or ecological effect (Cassel 1978), must be considered and judged according to general knowledge of species-specific movement patterns.

The present estimates should be judged along with mortality caused by similar obstacles. The primary distribution system (i.e. mainly 220 V) represents another 125 000 km (CBS 1992)), and telegraph wires (Televerket, personal communication) 1·3 mill. km. These overhead wires also take their toll. No database is available giving the location of these lines. Several reports from hunters and repair and maintenance employees in the power and communication sectors confirm that mortality takes place in connection with these air wires. In northern Norway, high mortality of willow ptarmigan has been shown to take place locally due to collisions with reindeer fences (K. Bevanger, unpublished). Local populations of capercaillie are being disturbingly reduced in Norway by destruction and fragmentation of forest biotopes (e.g. Wegge, Rolstad & Gjerde 1991). Several of the habitats most seriously affected by intensive forest exploitation are, moreover, located in areas with high overhead wire 'load'.

There are obviously limits to the 'load' of overhead wires which a species may endure within its habitat. Watson (1982) reported that the rock ptarmigan stock became extinct at a certain ski resort in Scotland due to mortality from collisions with the ski lift and tower wires. Miquet (1990) considered that mortality of black grouse as a result of collisions with ski-lift wires and power lines was a direct threat to populations in areas of France with 10 km of overhead wires per km^2.

Assessing tetraonid populations on the basis of estimates of mean losses per power-line kilometre should be done with care. Collision 'hot spots' exist even for resident species like tetraonids (Bevanger 1990b), implying a possible non-existent correlation between the recorded number of collisions and the length of power line (cf. Mathiasson 1993).

The overall length of the present 215 000 km of power lines in Norway will not be reduced in the years to come; rather it will increase because of the high cost of underground cabling, which is so far the only reliable mitigating measure that will significantly reduce the losses (Bevanger 1994). Thus, the most obvious way of balancing total mortality is to reduce other causes of death. Hunting activity may be controlled by means of, for instance, bag limits, a shorter hunting season or reducing the number of hunting licences sold. Although power-line-induced mortality can obviously be ignored in some areas, it should be seriously considered as an additional, negative factor locally, to which attention should be given when local management wildlife strategies are being prepared. Numerous local population reductions may give rise to national reductions eventually, which is important in view of future commitments to and emphasis on biodiversity.

Acknowledgements

I am indebted to Richard Binns for improving the English, the Defence Mapping Agency for providing digitized data for Norwegian power lines and, particularly, Lars Kvenild for help in estimating power line distances and Øyvind Bakke, John Atle Kålås, Hans Chr. Pedersen, Per Wegge and two anonymous referees for valuable comments on the manuscript.

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Received 4 November 1993; revision received 7 July 1994