T-LINES

Fauna norv. Ser. C, Cinclus 18: 41-51. 1995

Tetraonid mortality caused by collisions with power lines in boreal forest habitats in central Norway

Kjetil Bevanger

Bevanger, K. 1995. Tetraonid mortality caused by collisions with power lines in boreal forest habitats in central Norway. - Fauna norv., Ser. C, Cinclus 18: 41-51.

Collisions with power lines appear to be a source of systematic mortality for tetraonids in boreal forest habitats in central Norway. The clear-felled corridor along 7 sections of power lines (66, 72 and 132 kV) totaling 24.5 km was patrolled for a distance of 850 km. Fifty tetraonids collided with power lines, including 15 Capercaillie, 14 Black Grouse and 21 Willow Grouse. Some special methodological problems to assess mortality result from the low density of the species, and seasonal, climatic and habitat characteristics. The number of casualties found and the number of live birds observed during patrols was used to compare differences in the number of collisions between seasons, and determine species-specific differences in collision vulnerability. Power-line related mortality was higher ($p < 0.05$) in winter than in summer for Capercaillie, Black Grouse and Willow Grouse combined, but for only Capercaillie taken individually.

Kjetil Bevanger, Norwegian Institute for Nature Research, Division of Terrestrial Ecology, Tungasletta 2, N-7005 Trondheim, Norway.

INTRODUCTION

Evidence for birds colliding with power lines and telegraph wires is widespread (e.g. Avery 1978, Avery et al. 1980, Heijnis 1980, Longridge 1986, Faanes 1987, Hartman et al. 1992, Bevanger 1994, 1995). Such data have also been obtained from Norwegian forest habitats (Wadén 1904, Grotli 1922, Sørum 1950, Wilse 1951, Johannessen 1952, Swensen 1975, Stanghelle 1985), although all these are reports on accidentally observed victims, mainly concerning woodland game birds (Tetraonidae). Additional data from Fennoscandia, Britain and Central Europe indicate extensive mortality for some tetraonid species through colliding with various types of overhead wires (e.g. Hiltunen 1953, Watson 1982, Miquet 1990, Rose & Baillie 1992).

Studies in Europe and the United States on birds colliding with power lines were often "worst-case studies" concentrating on wetlands, roosting places, migration flyways, and other areas with high bird densities (Meyer 1978, James & Haak 1979, Heijnis 1980, Brown et al. 1987, Faanes 1987, Morkill & Anderson 1991). Only one study involved resident boreal forest birds colliding with power lines (Hiltunen 1953) in a "low density" environment.

The boreal forests in Norway constitute the western edge of the taiga, i.e. the boreal zone. The country has approximately 70 000 km^2 of productive coniferous and deciduous forest, representing about 23 % of the land area (CBS 1992). The main characteristics of these habitats are that snow cover in winter lasts for approximately 6 months with sharp seasonal contrasts. Limited resources and harsh weather during this period support only a few resident bird species in low densities (Merikallio 1946, Pianka 1989, Wiens 1989). However, 4 species of tetraonids are adapted to different succession stages of the Fennoscandian boreal forest - the Willow Grouse *Lagopus lagopus*, Black Grouse *Tetrao tetrix*, Capercaillie *T. urogallus* and Hazel Grouse *Bonasa bonasia* (Seiskari 1962, Jönsson et al. 1991).

The species concerned represent a valuable smallgame resource. To achieve sustainable harvest strategies, it is crucial to throughly understand all mortality factors. The objectives of the present study were to assess tetraonid collisions with power lines as a systematic mortality factor, to identify methodological problems and discuss biasing factors related to faunistical, seasonal, and habitat peculiarities, and to record the mortality rate by species and season.

STUDY AREA

The study area, located in central Norwegian upland forest in Sør-Trøndelag county (about 63° N, 10° E), comprised Spruce *Picea abies*, Pine *Pinus silvestris* and Birch *Betula* spp. interspersed with small bogs, but also including some low alpine habitats dominated by northern boreal birch forest (cf. Bevanger 1988 for detailed habitat description). It was chosen for its convenience as several categories of power lines were within a small area 60-80 km from the University of Trondheim. Seven sections of power line totaling 25.4 km and comprising 3 different tension categories (66, 72 and 132 kV) were patrolled for 850 km between 1984 and 1987 (**Table 1**).

Table 1. Technical data for 7 power-line sections searched for bird collision victims in forest habitats in central Norway during 1984-87.

Power-line section	1	2	3	4	5*	6	7	Total
Voltage (kV)	132	66	66	66	132	66	132	72
Length searched (km)	5.6	4.2	4.0	5.0	3.7	1.0	1.9	25.4
No. of patrols	43	36	17	27	46	43	22	234
Time and distance patrolled (km):								
June-August	67.2	42.0	0	30.0	25.9	6.0	0	171.1
September-October	11.2	8.4	0	35.0	25.9	4.0	0	84.5
November-March	84.0	67.2	44.0	20.0	51.8	15.0	32.3	314.3
April-May	78.4	33.6	24.0	50.0	66.6	18.0	9.5	280.1
Total distance patrolled	240.8	151.2	68.0	135.0	170.2	43.0	41.8	850.0
Patrol period (first/last patrol)	29.08.84 27.08.85	28.08.84 26.08.85	10.12.86 18.05.87	19.03.86 06.11.87	21.03.86 19.05.87	21.03.86 19.05.87	09.12.86 18.05.87	
No. of phase conductors/levels	6/3	3/1	3/1	3/1	3/1	6/3	3/1	6/3
Configuration	Double c stack	Single c flat (H)	Single c flat (H)	Single c flat (H)	Single c flat (H)	Double c stack	Single c flat (H)	Double c stack
Phase conductor diameter (mm)	30.0	10.0	10.7	10.7	21.7	16.7	21.7	16.7
Pole height (m) (ground to cross arm)	20-25	12-15	12-15	12-15	15-17	12-15	15-17	12-15
Distance between phase conductors (ca. m)	5.5	3.5	3.5	3.5	4.5	3.5	4.5	3.5
Construction year	1982	1926	1968	1968	1982	1979	1982	1979
Width of clear-felled corridor (ca. m)	24-32	16-20	16-20	16-20	24-32	16-20	16-20	

* Two parallel power lines. c = circuit, H = H-frame, wood structure.

Most power lines cross areas where Capercaillie, Black Grouse, Hazel Grouse and Willow Grouse live sympatrically. However, section 2 is in an area lacking Willow Grouse habitats and the distance patrolled was not included in the calculations for finding frequency of Willow Grouse. Sections 3 and 7 were not patrolled in summer or fall. The data from the 7 study sections were combined due to small sample sizes and for errors caused by possible annual population fluctuations.

Ecological factors form the basis for separating the data into 4 seasons. Summer (June-August) includes initiation of incubation and brooding (late May/early June) and birds remain on the ground. In the fall (September-October), the broods break up and the first snow normally falls by late October. Winter lasts 5 months (November to March), and at 63° N is characterized by snow cover (typically averaging about 1 m) and poor light conditions. Spring (April-May) is the mating season. Birds gather at leks resulting in increased flying between foraging areas, leks, and nesting areas. Snow melts in May.

DATA COLLECTION

Data were collected throughout the year by counting dead birds and remains, and live birds flushed in the clear-felled corridor below power lines and adjacent sites. During May-November, 1 person, accompanied by at least 2 pointing bird dogs (Gordon setters) searched the clear-felled area systematically by walking in a zig-zag pattern beneath the conductors along transects 16-32 m wide (**Table 1**). At least 1 trained dog located live birds, and another less experienced dog remained with the patroller helping to locate specimens. The patroller used skis or a snow scooter when needed.

Searches for collision victims were combined with observations of live birds along corridors to assess seasonal as well as species-specific differences. The dogs ranged beyond the corridor, covering approximately 50 to 100 m on each side of the power line. The additional area monitored varied according to local topography, tree density and snow conditions. Periods with deep, loose snow made efficient search extremely difficult. Most observations of live birds were made when they flushed due to presence of the observer or dogs.

All bird remains were collected. The time of death was estimated by body condition and separated into 5 categories: 1) ≤ 24 hrs, 2) the last 2 days, 3) the last week, 4) the last month, 5) > 1 month.

Flocking behaviour has been observed by Capercaillie (Pulliainen & Joensuu 1981, Pulliainen 1986), Black Grouse (Koskimies 1957) and Willow Grouse (Cramp & Simmons 1980) in most seasons. The term "flock" includes more than 1 individual observed at the same time (Pulliainen 1982b). For "live bird observations" singles and flocks are treated as 1 observation.

Patrols were made at irregular intervals from once a week to every third week and were not equally distributed in all seasons (**Table 1**). Varying weather and snow conditions influenced the number of days between patrols. When snow conditions were favourable, greater distances were patrolled by snow scooter, and are referred to as "non-standard patrols". Forty non-standard patrols covered 355 km along 14.1 kms of additional power lines.

STATISTICAL METHODS

Two measures were used to assess seasonal and species specific differences in collision mortality. The mortality index (F/O) is the ratio of number of casualties found (F) and number of live bird observations (O). It expresses variations in vulnerability for a species to collide with different types of power lines in different areas. The finding frequency (FF) is number of victims per 10 km of power line patrolled. It is primarily a quantitative measure but was used to assess seasonal differences in collision mortality, although number of birds present in the terrain is not taken into consideration. If, however, the population is assumed to remain relatively stable throughout the year, number of victims found per unit distance patrolled may indicate differences within an area. The finding frequency considers fieldwork effort, whereas the mortality index may be regarded independent of distance patrolled.

Because of the small numbers of victims (F) and live bird observations (O) for some species and seasons, significance probabilities for the F/O ratio were obtained by applying an exact simulation test instead of a chi-square test (see Kreiner 1987 for a review of analysis of contingency tables by exact tests). A contingency table gives the category of each of 2 criteria for each observation (e.g. the season and the dead/alive status for each bird observed). The simulation test was performed by permuting the categories observed randomly among the observations, independently for each of the two criteria, so that a new, simulated contingency table was obtained. This was repeated so that 1 000 contingency tables were simulated. For each simulation, the usual chi-square statistic was computed. They were sorted in descending order together with the single chi-square statistic for the original table, and the rank of the latter divided by 1002 was used as an estimate of the significance probability.

To test possible differences between the different seasons using finding frequency, it was assumed that number of casualties was Poisson distributed with expectation λ_{season}. The null hypothesis of $\lambda_{season1}$/km patrolled$_{season1}$ = $\lambda_{season2}$/km patrolled$_{season2}$, was tested against $\lambda_{season1}$/km patrolled$_{season1}$ > $\lambda_{season2}$/km patrolled$_{season2}$ etc.

RESULTS

Sixty-six corpses of 11 species were found; 50 (76 %) were tetraonids. Mortalities found during the non-standard patrols were excluded in calculations, but are shown in **Table 2.** Collision victims were found in all seasons, but no collisions occured in summer. No collisions were observed during field work. Hazel Grouse were not found or observed during patrols, although the species was observed in the study area.

Table 2. Collision victims recorded during standard patrols (additional casualties recorded on non-standard patrols in brackets) beneath 7 power-line sections in central Norway during 1984-87.

	Power-line section							
Species	1	2	3	4	5	6	7	Total
Capercaillie	6 (2)	2	1 (2)	2 (1)	4 (2)			15 (7)
Black Grouse	8	1	1	4 (1)				14 (1)
Willow Grouse	7		3 (1)	3 (6)	4	2	2 (1)	21 (8)
Other species (eight)	3	8	(1)	2 (3)	1 (1)	1	1	16 (5)
Total	25 (2)	12	5 (4)	11 (11)	9 (3)	3	3 (1)	66 (21)

Test of number
bird observations
differences in co
species pooled (
likely (p < 0.05
spring than sum
(p = 0.077) also i
in fall than sum
between fall, wi
nificant (p>0. 05

The Capercaillie
0.05) of hitting w
there were no si
for Black Gro
(p>0.05).

Test (two-sided
(**Table 3**) gave
0.025) for the Ca
than in summer,
collide in spring
ter. Black Grous
collision rates in
mer (p = 0.04 an

Most victims we
ductors, and ab
were within 5 m
ductors and mai
(**Table 4**).

table was obtained. This was at 1 000 contingency tables . For each simulation, the usual stic was computed. They were nding order together with the ıre statistic for the original rank of the latter divided by as an estimate of the signifi- ty.

: differences between the dif- ısing finding frequency, it was number of casualties was uted with expectation λ_{season}. esis of $\lambda_{season1}$/km patrolled$_{sea}$- m patrolled$_{season2}$, was tested /km patrolled$_{season1}$ > λ_{sea}- d$_{season2}$ etc.

s of 11 species were found; 50 aonids. Mortalities found dur- ıdard patrols were excluded in ut are shown in **Table 2.** ıs were found in all seasons, ; occured in summer. No colli- rved during field work. Hazel ot found or observed during h the species was observed in

tional casualties recorded on ns in central Norway during

6	7	Total
		15 (7)
		14 (1)
2	2 (1)	21 (8)
1	1	16 (5)
3	3 (1)	66 (21)

Test of number of collision victims and live bird observations (**Table 3**) showed seasonal differences in collision probabilities for the 3 species pooled ($p < 0.05$). Birds were more likely ($p < 0.05$) to hit wires in winter and spring than summer. The p-value for the fall ($p = 0.077$) also indicated higher collision risk in fall than summer. Collision probabilities between fall, winter and spring were not significant ($p>0.05$).

The Capercaillie had a higher probability ($p < 0.05$) of hitting wires during winter. However, there were no significant seasonal differences for Black Grouse and Willow Grouse ($p>0.05$).

Test (two-sided) of the finding frequency (**Table 3**) gave a higher probability ($p < 0.025$) for the Capercaillie to collide in winter than in summer, and for the Willow Grouse to collide in spring than in summer, fall and winter. Black Grouse tended to experience higher collision rates in fall and winter than in summer ($p = 0.04$ and $p = 0.05$, respectively).

Most victims were found beneath phase conductors, and about 70 % of the specimens were within 5 m of the terminate phase conductors and mainly in the clear-felled corridor (**Table 4**).

Table 3. Number of victims (F), number of live bird observations (O), mortality index (F/O) and finding frequency (FF) (number of victims per 10 km of power line) for Capercaillie, Black Grouse and Willow Grouse by season for 7 power-line sections patrolled in central Norway in 1984-1987. Flocks, broods, pairs and single birds are recorded as one observation.

Season/species	F	O	F/O	FF
Summer (June-August)				
Capercaillie	0	8	-	-
Black Grouse	0	5	-	-
Willow Grouse	0	5	-	-
Fall (September-October)				
Capercaillie	1	14	0.07	0.12
Black Grouse	3	3	1.00	0.35
Willow Grouse	0	6	-	-
Winter (November-March)				
Capercaillie	10	10	1.00	0.32
Black Grouse	7	16	0.44	0.22
Willow Grouse	5	26	0.19	0.16
Spring (April-May)				
Capercaillie	4	24	0.17	0.14
Black Grouse	4	18	0.22	0.14
Willow Grouse	16	40	0.40	0.38

Table 4. Locations of collision victims (%) from outside the terminate phase conductor along 7 power-line sections in central Norway during 1984-87 (specimens from non-standard patrols included).

Species	Beneath the conductors	Distance (m) from terminate phase conductor 1-5	6-10	11-15	>15
Capercaillie	15 (68.2)	1 (4.5)	2 (9.1)	3 (13.6)	1 (4.5)
Black Grouse	7 (46.7)	3 (20.0)	0	0	5 (33.3)
Willow Grouse	19 (65.5)	3 (10.3)	4 (13.8)	3 (10.3)	0
Other species	16 (76.2)	2 (9.5)	1 (4.7)	0	2 (9.5)

Autopsy of 9 specimens untouched by scavengers indicated that birds had hit wires across upper parts of the breast cutting the trachea and oesophagus. The sex ratio (f:m) of Capercaillie and Black Grouse specimens was 13/24. The probability that the number of males out of 37 birds is greater than or equal to 24, is 0.049; indicating males to have a greater probability of colliding than females ($p < 0.05$).

DISCUSSION

Mortality judgement

The number of victims confirm that power lines may be regarded as a systematic source of mortality for Capercaillie, Black Grouse and Willow Grouse, but not Hazel Grouse. However, low sample size precludes a clear assessment of the importance of power lines as a mortality factor, although any regularly occurring mortality per se is a negativ factor for population increase. To judge the significance of additional mortality is important for sustainable harvest and management of any species. The crucial question is whether the mortality is compensatory (e.g. Ellison 1991). Mortality peaked in winter and early spring for Capercaillie and Willow Grouse, implying that reproductive individuals were affected. Several game biologists (cf. Myrberget 1985, Ellison 1991) question whether additional mortality or over-exploitation of a population close to the breeding season can be compensated for by increased reproduction rates.

Quantitative estimates of power lines mortality of tetraonids on a regional or national scale is discussed by Bevanger (1995). Obviously there is a need for additional knowledge about population significance of mortality factors as power lines, hunting and predation (Baines & Lindén 1991, Ellison 1991, Storch & Willebrand 1991, Bevanger 1995).

Methodological aspects

Searches for injured or dead victims in or near power-line corridors are necessary to assess bird mortality. Assessment methods vary due to local adaptations. Most studies monitored the number of bird flights across power-line corridors, observed collisions, and number of dead birds found to estimate losses (Meyer 1978, James & Haak 1979, Beaulaurier 1981, Faanes 1987, Hartman et al. 1992). These methods are not suitable for resident populations of tetraonids at low densities. Studies of tetraonids in central Norway show fall population estimates of 7.5 Capercaillie, 4 Black Grouse and 5 Hazel Grouse per km^2 (Myrberget 1984). However, significant annual variation in numbers may occur.

Biases related to assessment of collision victims include habitat, search, crippling and scavenger removal (Meyer 1978, Beaulaurier 1981, Beaulaurier et al. 1984, Faanes 1987, Hartman et al. 1992, Bevanger 1995) and are common to mortality studies regardless of geographical area. It is not possible to predict general correction factors for various studies as they are all dependent upon a variety of local conditions. Consequently, it is necessary to make local "bias tests" to obtain correction factors for quantitative estimates.

A primary problem in the boreal forest is that snow covers shrubs and short vegetation and fills in small depressions from November through April/May. However, the use of dogs may improve the reliability of mortality surveys.

Several victims were not found until spring. In these situations, it was not possible to determine when mortalities occurred. It was also difficult to separate specimens into the 5 categories. In May, visible feather remains did not persist because numerous migratory passer-

ines returned
material.

Crippling bia
ger abundanc
and meteorol
could be asse
ter tagging o
population.

Scavenger a
authors (Sc
Longridge 1
1987, Hoersc
al. 1994). In
not remain l
included H
Ravens *C.*
chrysaëtos
Specimen re
turnover, esp
1994).

General as
seasonal d

Three conclu
lisions with
of systemat
there are sea
tality index
the collisior
Grouse and
acteristics.

Tetraonids
power lines
vision (Bev
considered
high wing l
(Rayner 19
ceous specie
fovea, bein
fovea is con
to very goo

ines returned and used feathers for nesting material.

Crippling bias will vary according to scavenger abundance, local topographical, technical and meteorological conditions. Crippling bias could be assessed by extensive radio transmitter tagging of a proportion of the resident bird population.

Scavenger activity is addressed by various authors (Scott et al. 1972, Heijnis 1980, Longridge 1986, Rusz et al. 1986, Faanes 1987, Hoerschelmann et al. 1988, Bevanger et al. 1994). In the boreal forest, specimens do not remain long. Scavengers in the study area included Hooded Crows *Corvus corone*, Ravens *C. corax*, Golden Eagles *Aquila chrysaëtos* and Red Fox *Vulpes vulpes*. Specimen removal studies indicated a rapid turnover, especially in spring (Bevanger et al. 1994).

General aspects, species-specific and seasonal differences

Three conclusions from the study are: (i) collisions with power lines appear to be a source of systematic mortality for tetraonids, (ii) there are seasonal variations in both the mortality index and the finding frequency, and (iii) the collision pattern of Capercaillie, Black Grouse and Willow Grouse have certain characteristics.

Tetraonids are vulnerable to colliding with power lines because of flight ability and vision (Bevanger 1994). They are generally considered poor flyers, having short wings, high wing loading and rather high aspect ratio (Rayner 1988, Norberg 1990). Most gallinaceous species lack or have a poorly developed fovea, being afoveal (Sillman 1973). The fovea is considered to be a point that gives rise to very good acuity or resolution because of the large number of cones per unit area. Lack of good acuity may reduce the ability of the birds to cope well with artificial obstacles like air wires during a stress situation, or in bad weather and poor light.

Due to poor light in winter at these latitudes, collisions with power lines should peak. In mid winter, daytime is a continuous dusk period. However, only for the Capercaillie both the F/O ratio and finding frequency gave a statistically significant higher collision probability in winter than in summer. This may reflect more frequent flying among the Capercaillie than the Black Grouse and Willow Grouse. Black Grouse may spend as much as 94 % of their time in snow burrows during strong wind and poor weather. Capercaillie roosts in the snow in February and March in Finland (Marjakangas 1980, 1992), and Semenov-Tjan-Sanskij (1960) reported that they spent up to 80 % of the time in burrows. Because of the body size, successful roosting, however, depends on favourable snow conditions (Pulliainen 1982a). A lowered winter collision mortality for Black Grouse may be related to its morning activity (favourable light conditions). Other grouse species have a major activity peak in the evening (poor light conditions) (Marjakangas 1992).

The absence of Hazel Grouse is probably explained by its behaviour and habitat requirements. Between September and April, it is an arboreal feeder and has clumped distribution owing to patchy distributed biotopes (Swenson 1991). The Hazel Grouse in Fennoscandia is confined to extremely dense, unmanaged spruce forests interspersed with alder *Alnus* spp. and birch, a biotope avoided by the Capercaillie and Black Grouse (Swenson 1991). This biotope is increasingly less common due to forestry practices. It is also territorial most of the year and occurs as singles or pairs within relatively small winter territories (Swenson 1991). The Hazel Grouse is easily overlooked, even by bird dogs. Restricted flying activity in densely forested habitats and few power lines in Hazel Grouse biotopes make the species less vulnerable to collisions.

Collision mortality peaked during spring for Willow Grouse, probably due to territorial flights. Capercaillie and Black Grouse have an active lekking period in April-May (Rolstad et al. 1988, Willebrand 1988, Gjerde & Wegge 1989). Birds frequently move locally between feeding grounds and lek arenas during twilight and poor light conditions. Power lines crossing lekking areas at a critical height (e.g. immediately above the tree tops), posed a high risk to the species (Bevanger 1990). Black Grouse was documented (Hjort 1968) to arrive at the lek site when light conditions were only between 0.01 and 0.05 lux in mid April. Flight under these conditions is close to the lower limit when orientation to the lek arena is possible (Hjort 1968), and power lines would be very difficult to see, and pose a serious hazard.

Lack of summer mortalities may be due to decreased detectability because increased vegetation cover. Also low summer collision rates are related to egg laying, incubation, a long period of juvenile care and minimal flight activities.

Increased mortality is expected in fall due to young birds flying. Black Grouse may suffer a high fall mortality because they perform a display, when birds congregate at lek arenas. Although the fall display activity is less frequent than in the spring period, it may take place during periods when light intensities are as low as 0.5 lux (Hjort 1968).

The differences in sex distribution of the Capercaillie and Black Grouse victims may be due to dark coloured male feathers are more easily seen than the female feathers. The larger body size of the males (Black Grouse 1 000-1 750 g, Capercaillie 3 720-4 900 g) (Haftorn 1971) may reduce scavenger removal as they often are consumed on site leaving numerous feather remains. Moreover, significant annually and regionally variations in sex ratio was found for Capercaillie and Black Grouse in Finland (Rajala 1974), and differences in spacing and habitat use for male and female Capercaillie in summer was observed in Norway (Rolstad et al. 1988). The smaller females seemed to adopt a "hiding" strategy in fairly dense habitats (e.g. young plantations) (Rolstad et al. 1988). Spatial separation for the Black Grouse sexes have also been found (Willebrand 1988). A difference in adaptation to niches may locally affect the collision rate.

ACKNOWLEDGEMENTS

The study was financed by the Applied Ecology Research Programme (ØKOFORSK). Terje Dalen and the Gordon setters "Rici", "Bliss", "Dino" and "Iso" provided crucial cooperation during the field work. I am also grateful to two anonymous referees, Hans Chr. Pedersen and several colleagues at the Norwegian Institute for Nature Research for valuable comments on the manuscript, Øyvind Bakke for advice on the use of statistics, Steinar Engen for developing the simulation test program and Richard Binns for improving the English.

SAMMENDRAG

Dødelighet hos skogshøns i boreale skogområder i Midt-Norge på grunn av kollisjoner mot kraftledninger

Kollisjoner mot kraftledninger synes å være en regulær dødelighetsfaktor for skogshøns (tetraonider) i boreale skogområder i Midt-

Norge. Ryddebel
ningsavsnitt (66,
24,5 km ble patı
Femti hønsefugl
ledningene; 15
ryper. På grunn a
fugl i slike områ
tiske variasjoner
het, oppstår en ı
tilknytning til da
sjonsoffer funne
observert under ı
sammenligne ses
lisjonshyppighet
sårbarhet i forho
som følge av kc
var høyere om vi
de tre artene sett
fugl når de ble te

REFERENCES

Avery, M. L., ed
sion lines on bi
a conference Ja
Ridge Associat
Avery, M.L., Sp
1980. Avian m
tures: an annot
U.S. Fish and V
National Powe
80/54.
Baines, D. & Linc
mary: The impa
lation dynamics
Beaulaurier, D. I
collisions with
Dept. of Energy
Administration
Energy, Oregon
Beaulaurier, D.L.,
Meyer, R.J. &
the incidence o
mission lines.
A.F. (ed.). P

.les (Black Grouse
lie 3 720-4 900 g)
ɜ scavenger removal
ıed on site leaving
. Moreover, signifi-
lly variations in sex
ercaillie and Black
ı 1974), and differ-
:at use for male and
nmer was observed
1988). The smaller
a "hiding" strategy
e.g. young planta-
): Spatial separation
ces have also been
ı. A difference in
locally affect the

 NTS

l by the Applied
ogramme (ØKO-
the Gordon setters
nd "Iso" provided
the field work. I am
nous referees, Hans
l colleagues at the
ature Research for
the manuscript,
on the use of statis-
eloping the simula-
Richard Binns for

ıs i boreale skog-
grunn av kollisjo-

nger synes å være
tor for skogshøns
ogområder i Midt-

Norge. Ryddebeltet i tilknytning til 7 kraftledningsavsnitt (66, 72 og 132 kV) på tilsammen 24,5 km ble patruljert gjennom i alt 850 km. Femti hønsefugler hadde kollidert med kraftledningene; 15 storfugl, 14 orrfugl og 21 ryper. På grunn av den lave tettheten av hønsefugl i slike områder, sesongmessige og klimatiske variasjoner samt habitatenes beskaffenhet, oppstår en rekke metodiske problemer i tilknytning til datainnsamlingen. Antall kollisjonsoffer funnet og antall levende fugler observert under patruljeringene ble brukt til å sammenligne sesongmessige forskjeller i kollisjonshyppighet og identifisere artsspesifikk sårbarhet i forhold til kollisjoner. Dødelighet som følge av kollisjoner mot kraftledninger var høyere om vinteren enn om sommeren for de tre artene sett under ett, men bare for storfugl når de ble testet hver for seg.

REFERENCES

Avery, M. L., ed. 1978. Impacts of transmission lines on birds in flight. - Proceedings of a conference January-February 2, 1978 Oak Ridge Associated Universities, Tennessee.

Avery, M.L., Springer, P.F. & Dailey, N.S. 1980. Avian mortality at man-made structures: an annotated bibliography (revised). - U.S. Fish and Wildl. Serv. Biol. Serv. Prog., National Power Plant Team, FWS/OBS-80/54.

Baines, D. & Lindén, H. 1991. Workshop summary: The impact of hunting on grouse population dynamics. - Ornis Scand. 22: 245-246.

Beaulaurier, D. L. 1981. Mitigation of bird collisions with transmission lines. - U.S. Dept. of Energy, Oregon. Bonneville Power Administration Report. U.S. Dept. of Energy, Oregon.

Beaulaurier, D.L., James, B.W., Jackson, P.A., Meyer, R.J. & Lee, J.M. 1984. Mitigating the incidence of bird collisions with transmission lines. - Pp. 539-550 in Crabtree, A.F. (ed.). Proceedings of the Third International Symposium on Environmental concerns in Right-Of-Way Management, San Diego, Calif., February 15-18, 1992. Mississippi State University, Mississippi.

Bevanger, K. 1988. Transmission line wirestrikes of Capercaillie and Black Grouse in central Norwegian coniferous forest. - Økoforsk Report 9: 1- 53 pp. (In Norwegian with English summary).

Bevanger, K. 1990. Topographic aspects of transmission wire collision hazards to game birds in the central Norwegian coniferous forest. - Fauna norv. Ser. C, Cinclus 13: 11-18.

Bevanger, K. 1994. Bird interactions with utility structures: collision and electrocution, causes and mitigating measures. - Ibis 136: 412-425.

Bevanger, K. 1995. Estimates and population consequences of tetraonid mortality caused by collisions with high tension power lines in Norway. - J. Appl. Ecol. 32: (in press).

Bevanger, K., Bakke, Ø. & Engen, S. 1994. Corpse removal experiment with Willow Ptarmigan (*Lagopus lagopus*) in power-line corridors. - Ökol. Vögel. (Ecol. Birds) 16: (597-607).

Brown, W.M., Drewien, R.C. & Bizeau, E.G. 1987. Mortality of cranes and waterfowl from powerline collisions in the San Luis Valley, Colorado. - Pp. 128-136 in Lewis, J.C., (ed.). Proceedings 1985, Crane Workshop. Platte River Whooping Crane Trust and U.S. Fish Wildl. Serv. Grand Island, Nebr.

CBS. 1992. Natural resources and the environment. - Central Bureau of Statistics of Norway. Report 92/1A. Oslo-Kongsvinger.

Cramp, S. & Simmons, K.E.L. 1980. Handbook of the birds of Europe the Middle East and North Africa. Vol. 2. - Oxford Univ. Press, Oxford.

Ellison, L. N. 1991. Shooting and compensatory mortality in tetraonids. - Ornis Scand. 22: 229-240.

Faanes, C. A. 1987. Bird behavior and mortality in relation to power lines in prairie habitats. - U.S. Fish Wildl. Serv. Tech. Report 7.

Gjerde, I. & Wegge, P. 1989. Spacing pattern, habitat use and survival of Capercaillie in a fragmented winter habitat. - Ornis Scand. 20: 219-225.

Grotli, S. 1922. Fugledrap ved luftledninger. - Norsk Orn. Tidsskr. 1: 125-126.

Haftorn, S. 1971. Norges fugler. - Universitetsforlaget, Oslo.

Hartman, P. A., Byrne, S. & Dedon, M.F. 1992. Bird mortality in relation to the Mare Island 115-kV transmission line: Final report 1988-1991. - Dept. of Navy, Western Div., Cal. PG&E Report 443-91.3.

Heijnis, R. 1980. Vogeltod durch Drahtanflüge bei Hochspannungsleitungen. - Ökol. Vögel (Ecol. Birds) 2, Sonderheft: 111-129.

Hiltunen, E. 1953. Om de förluster som flygning mot ledninger förorsakar hönsfåglarna. - Suomen Riista 8: 70-76, 200-201.

Hjort, I. 1968. Significance of light in the initiation of morning display of the Black Grouse (*Lyrurus tetrix* L.). - Viltrevy 5: 1-94.

Hoerschelmann, H., Haack, A. & Wohlgemuth, F. 1988. Verluste und Verhalten von Vögeln an einer 380 kV Freileitung. - Ökol. Vögel (Ecol. Birds.) 10: 85-103.

James, B. W. & Haak, B.A. 1979. Factors affecting avian flight behavior and collision mortality at transmission lines. - Bonneville Power Administration Report. U.S. Dept. of Energy, Oregon.

Johannessen, E. 1952. Ledningene dreper. - Jeger og Fisker 81: 143-144.

Jönsson, K. I., Angelstam, P.K. & Swenson, J. 1991. Patterns of life-history and habitat in Palearctic and Nearctic forest grouse. - Ornis Scand. 22: 275-281.

Koskimies, J. 1957. Flocking behaviour in Capercaillie, *Tetrao urogallus* L., and blackgame, *Lyrurus tetrix* (L.). - Pap. Game Res. 18: 1-32.

Kreiner, S. 1987. Analysis of multidimensional contingency tables by exact conditional tests: techniques and strategies. - Scand. J. Statist. 14: 97-112.

Longridge, M. W. 1986. The impacts of transmission lines on bird flight behaviour, with reference to collision mortality and systems reliability. - Bird Res. Comm., ESCOM Report, Johannesburg.

Marjakangas, A. 1980. Snow roosting in tetraonids, Tetraonidae. - Memoranda Soc. Fauna Flora Fenn. 56: 65-70.

Marjakangas, A. 1992. Winter activity patterns of the Black Grouse *Tetrao tetrix*. - Ornis Fennica 69: 184-192.

Merikallio, E. 1946. Über regionale Verbreitung und Anzahl der Landvögel in Süd- und Mittelfinnland, besonders in deren Östlichen Teilen, im Lichte von Quantitativen Untersuchungen. - Ann. Zool. Soc. Zool. Bot. Fenn. Vanamo, 12: 1-138.

Meyer, J.R. 1978. Effects of transmission lines on bird flight behavior and collision mortality. - Bonneville Power Administration Report. U.S. Dept. of Energy, Oregon.

Miquet, A. 1990. Mortality in Black Grouse *Tetrao tetrix* due to elevated cables. - Biol. Conserv. 54: 349-355.

Morkill, A.E. & Anderson, S.H. 1991. Effectiveness of marking powerlines to reduce sandhill crane collisions. - Wildl. Soc. Bull. 19: 442-449.

Myrberget, S., ed. 1984. The Norwegian Woodland Grouse Project. - DVF Viltforskningen. Viltrapport 36: 1-103. (In Norwegian with English summary).

Myrberget, S. 1985. Is hunting mortality compensated for in grouse populations, with special reference to willow grouse? - Pp. 329-336 in Crombrugghe, S.A. (ed.). Transactions of the XVIIth Congress og the International Union of Game Biologists, Brussels, Belgium, September 17-21, 1985. Ministery of Agriculture, Brussels, Belgium.

Norberg, U. M. 1990. Vertebrate flight. - SpringerVerlag, New York.

Pianka, E. R. 1989. Latitudinal gradients in species diversity. - TREE 4: 223.

Pulliainen, E. 1982a. Breeding, foraging and wintering strategies of the Black Grouse,

M. W. 1986. The impacts of transnes on bird flight behaviour, with to collision mortality and systems - Bird Res. Comm., ESCOM hannesburg.

, A. 1980. Snow roosting in tetratraonidae. - Memoranda Soc. ra Fenn. 56: 65-70.

, A. 1992. Winter activity pate Black Grouse *Tetrao tetrix*. - ica 69: 184-192.

E. 1946. Über regionale g und Anzahl der Landvögel in Mittelfinnland, besonders in deren Teilen, im Lichte von en Untersuchungen. - Ann. Zool. Bot. Fenn. Vanamo, 12: 1-138.

1978. Effects of transmission lines ght behavior and collision mortalonneville Power Administration S. Dept. of Energy, Oregon.

1990. Mortality in Black Grouse ix due to elevated cables. - Biol. 4: 349-355.

E. & Anderson, S.H. 1991. ess of marking powerlines to dhill crane collisions. - Wildl. 19: 442-449.

S., ed. 1984. The Norwegian Grouse Project. - DVF ngen. Viltrapport 36: 1-103. (In with English summary).

. 1985. Is hunting mortality comr in grouse populations, with spece to willow grouse? - Pp. 329-nbrugghe, S.A. (ed.). Transactions Ith Congress og the International Game Biologists, Brussels, eptember 17-21, 1985. Ministery re, Brussels, Belgium.

M. 1990. Vertebrate flight. - rlag, New York.

. 1989. Latitudinal gradients in ersity. - TREE 4: 223.

. 1982a. Breeding, foraging and strategies of the Black Grouse, *Lyrurus tetrix* L., in the Finnish taiga - a review. - Aquilo Ser. Zool. 21: 68-75.

Pulliainen, E. 1982b. Flocking behaviour of the Capercaillie (*Tetrao urogallus*) and conservation strategy for the species. - Pp. 36-43 in Lovel, T.W. I. (ed.). Proceeding on the Second International Symposium on Grouse, Dalhousie Castle, Edinburgh, Scotland, March 16-21 1981. World Pheasant Association, Suffolk, England.

Pulliainen, E. 1986. Flocking of Capercaillie, *Tetrao urogallus*, in eastern Finnish Lapland in winter. - Ornis Fenn. 63: 56-57.

Pulliainen, E. & Joensuu, O. 1981. Flocking of male Capercaillie *Tetrao urogallus* at feeding sites in Ostrobothnia, W. Finland. - Ornis Fenn. 58: 131-133.

Rajala, P. 1974. The structure and reproduction of Finnish populations of Capercaillie, *Tetrao urogallus*, and Black Grouse, *Lyrurus tetrix*, on the basis of late summer census data from 1963-1966. - Finnish Game Res. 35: 1-51.

Rayner, J. M. V. 1988. Form and function in avian flight. - Pp. 670-679 in Johnston, R.F. (ed.). Current Ornithology. Vol. 5. Plenum, New York.

Rolstad, J., Wegge, P. & Larsen, B.B. 1988. Spacing and habitat use of Capercaillie during summer. - Can. J. Zool. 66: 670-679.

Rose, P. & Baillie, S. 1992. The effects of collisions with overhead wires on British birds: an analysis of ringing recoveries. - British Trust Ornithology Res. Report 42.

Rusz, P. J., Prince, H.H, Rusz, R.D. & Dawson, G.A. 1986. Bird collisions with transmission lines near a power plant cooling pond. - Wild. Soc. Bull. 14: 441-444.

Scott, R. E., Roberts, L.J. & Cadbury, C.J. 1972. Bird deaths from power lines at Dungeness. - Brit. Birds 65: 273-286.

Seiskari, P. 1962. On the winter ecology of the Capercaillie, *Tetrao urogallus*, and the Black Grouse, *Lyrurus tetrix* in Finland. - Pap. Game Res. 22: 1-118.

Semenov-Tjan-Sanskij, O. 1960. Ekologija teterevinyh ptits. - Trudy Laplandskogo Gosudarstvennogo Zapovednika 5: 1-318.

Sillman, A. J. 1973. Avian vision. - Pp. 349-387 in Farner, D.S. & King, J.R. (eds.). Avian biology. Vol. III. Academic Press, London.

Stanghelle, E. 1985. Jo, høyspentlinjene tar mye fugl! - Villmarksliv 13: 73.

Storch, I. & Willebrand, T. 1991.Management implications of nest and brood predation in grouse. - Ornis Scand. 22: 271-272.

Swensen, G. 1975. Unødige naturforringelser. - Jakt Fiske Friluftsliv 104: 23, 43.

Swenson, J. E. 1991. Social organization of Hazel Grouse and ecological factors influencing it. - Ph.D. thesis, University of Alberta.

Sørum, L. 1950. Fugleviltundersøkelser på laboratoriet. - Jeger og Fisker 79: 55-65.

Wadén, D. J. 1904. Diskusjonskommentar. - Norges Jeger- og Fiskerforbunds Tidsskr. 33: 257.

Watson, A. 1982. Effects of human impact on ptarmigan and red grouse near skilifts in Scotland. - P. 51 in Annual Report Institute of Terrestrial Ecology, February 1981, Cambridge.

Wiens, J. A. 1989. The ecology of bird communities. Vol. 1. - Cambridge University Press, Cambridge.

Willebrand, T. 1988. Demography and ecology of a Black Grouse (*Tetrao tetrix* L.) population. - Ph.D. thesis, University of Uppsala, Sweden.

Wilse, E. 1951. Hvilken rolle spiller kraft- og telefonledninger når det gjelder desimeringen av vår bestand av matnyttig fuglevilt? - Jeger og Fisker 80: 197-198.