NINA Report 504

"Optimal design and routing of power lines; ecological, technical and economic perspectives" (OPTIPOL)

Progress Report 2009

Kjetil Bevanger, Gundula Bartzke, Henrik Brøseth, Jan Ove Gjershaug, Frank Hanssen, Karl-Otto Jacobsen, Pål Kvaløy, Roel May, Torgeir Nygård, Hans Christian Pedersen, Ole Reitan, Steinar Refsnæs, Sigbjørn Stokke, Roald Vang

CEDREN Centre for Environmental Design of Renewable Energy

Forskningsrådet Norges vassdrags- og energidirektorat NVE Statnett EBL Energibedriftenes landsforening BKK

NINA Norwegian Institute for Nature Research

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Norwegian Institute for Nature Research

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COVER PICTURE
Left: Woodpecker scaring device on a power-line pylon. Photo: Kjetil Bevanger. Right: Illustration photo of wire marking equipment.

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Abstract

Bevanger, K., Bartzke, G., Brøseth, H., Gjershaug, J.O., Hanssen, F., Jacobsen, K.-O., Kvaløy, P., May, R., Nygård, T., Pedersen, H.C., Reitan, O., Refsnæs, S., Stokke, S. & Vang, R. 2009" Optimal design and routing of power lines; ecological, technical and economic perspectives" (OPTIPOL). Progress Report 2009. – NINA Report 504. 46 pp.

From 2009 inclusive, NINA has received economic support for research on power lines and wildlife from the Norwegian Research Council (NFR) through the RENERGI Programme. The project is named "*Optimal design and routing of power lines; ecological, technical and economic perspectives*" (OPTIPOL). It is scheduled for 5 years (2009-1013) and is part of the activities within CEDREN, i.e. the *Centre for environmental design of renewable energy* (cf. http://www.cedren.no). With a grid close to 200 000 km overhead power-lines, the associated rights-of-way (ROW) affect huge land areas in Norway. The overall goal is to develop predicting tools for optimal routing of power lines from an environmental perspective and assess technical and economic solutions to minimize conflicts with wildlife and habitat conservation. Thus, the OPTIPOL rationale is based on the belief that the negative effects of electricity transmission and distribution can be reduced with respect to birds and mammals. OPTIPOL has several ambitious objectives, and is divided into sub-projects and specific tasks. From the first of November a PhD-student became part of the project, a position that will be held for 4 years. The main objective of the PhD-activities will be to assess how and why different wildlife species use deforested areas below power lines, evaluate possible positive and negative effects of power-line ROWs, and assess the possibilities for quality improvement. Another part of the project is dedicated the effects of linear structures on movement patterns and distribution in the landscape in native deer species. Here we will examine how different spatial scales influence the processes that guide movement patterns, and responses to linear structures. Another focus will be small game species, with mountain hare, capercaillie, black grouse and hazel grouse as model species. The main objective will be to assess the impact of transforming ROW habitats into attractive small-game foraging habitats. Moreover avoidance behaviour of gallinaceous birds towards power-line corridors will be studied, using capercaillie and hazel grouse as model species. Finally, mortality rates due to power-line collisions, relative to other human-related mortality factors (primarily hunting) among gallinaceous birds will be assessed, using capercaillie and black grouse as model species. Efforts to identify how topographic factors, including vegetation structure, affect bird-collision risk also are part of this work package. A wachtelhund, born in September 2009, is now being trained to locate dead birds in power-line corridors. The efforts to identify species- and site-specific factors regarding bird collisions with power lines is also the rationale behind a subproject where we are developing an online web application for registering dead bird data via Internet. We will target as many relevant users as possible and existing bird-collision data from various projects in NINA will also be imported into the database. A functional prototype of the web application is finished, and incorporates topographical maps, and the possibility of overlaying power-line maps. The work with a Least Cost Path (LCP) toolbox for optimal routing of power lines has started. A pilot LCP-GIS-toolbox has been developed and will be further developed in 2010. Data from the national power-line database from NVE has been organised for internal use in a restricted/classified database at NINA. These data are used together with ecological background data to identify case-study areas. The first stage of the work on power-line colour camouflaging and mitigating measures regarding bird collisions and electrocution are made as reviews studies and will be finalized in 2010. Guidelines for technical solutions to mitigate bird collisions and electrocution hazard have started and will be an important part of the work in 2010. The eagle-owl is used as a model species in connection to the studies of electrocution mitigating measures. The study includes use of GPS-satellite telemetry to see how the eagle owls use the pylons during hunting activities. This will also give data on eagle-owl movements and electrocution rate. In 2009 3 adult and 4 juvenile eagle owls were equipped with GPS-radio transmitters.

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Sammendrag

Bevanger, K., Bartzke, G., Brøseth, H., Gjershaug, J.O., Hanssen, F., Jacobsen, K.-O., Kvaløy, P., May, R., Nygård, T., Pedersen, H.C., Reitan, O., Refsnæs, S., Stokke, S. & Vang, R. 2009” Optimal design and routing of power lines; ecological, technical and economic perspectives” OPTIPOL). Progress Report 2009. – NINA Rapport 504. 46 s.

Fra og med 2009 har NINA mottatt økonomisk støtte til forskning på kraftledninger og vilt fra Norges Forskningsråd via RENERGI-programmet. Prosjektet heter “*Optimal design and routing of power lines; ecological, technical and economic perspectives*” (OPTIPOL). Det er planlagt for 5 år (2009-2013) og er en del av aktivitetene i forskningssenteret CEDREN, dvs. *Centre for environmental design of renewable energy* (cf. http://www.cedren.no). Norges kraftledningsnett utgjør nærmere 200 000 km luftledninger som til sammen berører store arealer. Den overordnede målsettingen for prosjektet er å utvikle verktøy som ut fra et miljøsynspunkt kan bidra til å optimalisere trasévalget når kraftledninger bygges, samt vurdere tekniske og økonomiske løsninger for å minimalisere konflikter *vis-a-vis* vilt og dyrenes leveområder. Bakgrunnen for prosjektet er m.a.o. behovet for å redusere negative effekter av kraftoverføring i forhold til fugl og pattedyr. OPTIPOL har flere ambisiøse delprosjekter som fokuserer spesifikke problemstillinger. Fra første november ble det ansatt en PhD-student i en fireårskontrakt. Hovedfokus i tilknytning til dette arbeidet vil være aktiviteter som ser på hvordan og hvorfor ulike viltarter bruker ryddebeltene i tilknytning til kraftledninger, og evaluering av mulige positive og negative effekter av kraftledningsgater, samt hvordan disse kvalitativt sett kan forbedres. En annen viktig del av prosjektet er viet studier av hvordan terrengbruken hos hjortevilt påvirkes av lineære strukturer i tid og rom og hvordan hjortevilt responderer i forhold til romlige bruksmønstre på ulike nivå. I forhold til småvilt vil fokus være hare, storfugl, orrfugl og jerpe; arter som er egnede modellarter i forhold til flere problemstillinger. Studiene vil fokusere på hvordan kraftledningsgater kan manipuleres for å bli attraktive næringshabitater for småvilt, samt eventuelle unnvikelseseffekter i forhold til kraftledningskorridorer. Dødelighetsomfang som følge av kollisjoner med kraftledninger, sammenlignet med andre menneskeinduserte dødelighetsfaktorer (i første rekke jakt), hos hønsefugl vil også bli vurdert med utgangspunkt i storfugl, orrfugl og jerpe. Det vil også bli arbeidet med å identifisere hvordan bl.a. topografiske faktorer, inklusive vegetasjonsstruktur, påvirker omfang av fuglekollisjoner. En wachtelhund, født i september 2009 blir nå spesialtrenet til å lokalisere kollisjonsdrepte fugler. Målet om å identifisere arts- og stedsspesifikke faktorer som påvirker fuglekollisjoner ligger også bak et av delprosjektene der vi utvikler en online web applikasjon for å registrere funn av døde fugler via Internett. Dette er rettet mot så mange relevante brukere som mulig. Eksisterende databaser med slike opplysninger fra tidligere prosjekter i NINA vil også bli innlemmet. En funksjonell prototype av web-applikasjonen er ferdigstilt og omfatter topografiske kart samt muligheter for å legge på kartlag med kraftledninger. Arbeidet med et “Least Cost Path” (LCP) verktøy for optimal traséføring av kraftledninger er også påbegynt. En pilotversjon av en ”LCP-GIS-toolbox” er utviklet og vil bli videreutviklet i 2010. Data fra den nasjonale databasen over kraftledningsnettet fra NVE er tilrettelagt for internt bruk i en database med begrenset tilgang ved NINA. Dette er data som blir benyttet sammen med økologiske bakgrunnsdata for bl.a. å identifisere optimale studieområder. Det innledende arbeidet med vurdering av effekter av fargekamuflering av kraftledninger og avbøtende tiltak i forhold til fuglekollisjoner og elektrokusjon er påbegynt, og omfatter så langt litteraturgjennomgang og en oppsummering av ”state-of-the-art”. Denne første fasen forventes avsluttet i 2010. Guidelines for tekniske løsninger for å avhjelpe elektrokusjonsfare er også kommet godt i gang og vil være en viktig del av virksomheten i 2010. Hubro brukes som modellart i tilknytning til studier av elektrokusjons- og kollisjonsproblematikk og i arbeidet med å komme frem til avbøtende tiltak som både er akseptable fra et teknisk og økologisk synspunkt. Dette arbeidet omfatter bruk av satellittelemetri for bl.a. å studere hvordan hubro benytter kraftledningsstolper under jakt. Det vil også gi data om bevegelsesmønster og elektrokusjonsomfang. I 2009 ble 3 voksne og 4 reirunger utstyrt med radiosendere.

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Contents

Foreword

From 2009 inclusive, NINA has received economic support for research on power lines and wildlife from the Norwegian Research Council (NFR) through the RENERGI Programme. The project is named "*Optimal design and routing of power lines; ecological, technical and economic perspectives*" (OPTIPOL). It is a capacity building project with user participation (KMB). The project has a comprehensive and challenging goal framework, as much economic as scientific, and can only be carried out within a team of scientific experts with ecological as well as engineering background. Moreover, a close cooperation with the central energy and environmental-management authorities together with the energy sector, particularly the grid owners, is a prerequisite. Apart from the Norwegian Water Resources and Energy Directorate (NVE), the Norwegian Electricity Industry Association (EBL), and Statnett at the outset committed themselves to contribute with an annual economic support to the project (at least 20% of the total costs). OPTIPOL is an integrated part of CEDREN – i.e. the *Centre for environmental design of renewable energy*. CEDREN is one of 8 Centre for Environment-friendly Energy Research (CEER) in Norway. The establishment of the CEER scheme is a direct response to the broad-based agreement on Norway's climate policy in the Norwegian Parliament (Stortinget), reached early in 2008, and the adoption of the national R&D strategy *Energi21.* Norway has decided to earmark at least NOK 100 million per year to the CEER initiative. For the Norwegian research institutions the application process started in May 2008 and a final decision on the winners was taken by the Research Council Executive Board - 28 January 2009, and the official announcement was made by the Minister of Oil and Energy February 4 2009. CEDREN is a consortium with SINTEF, NTNU and NINA as key institutions. SINTEF is responsible for co-ordinating the CEDREN activities and the basic funding comes from NFR, together with users like Statkraft, Statnett, EBL, NVE etc. Thus the basic activities within CEDREN are based on the ongoing activities in OPTIPOL and 6 other KMB projects. The overall objective of CEDREN is to *develop and disseminate effective design solutions for renewable energy production that take adequate account of environmental and societal issues, both locally and globally*. The OPTIPOL project is scheduled for 5 years (2009-1013), however, because of a delayed start in CEDREN; it is likely that the project will finish in 1014.

Trondheim, 1 December 2009

Kjetil Bevanger
Project leader

1 Introduction

With an overhead power-line grid close to 200 000 km in Norway (http://www.ssb.no/elektrisitetaar/tab-2009-05-28-08.html), the associated rights-of-way (ROW) affect huge land areas. Landowners of forested areas criss-crossed by power lines generally look at these clear-felled areas as "wasteland". However, clear-felled areas beneath the power-line conductors in forest habitats are biotopes attractive to some species. It is a challenge to improve these biotopes in a manner that attract more species; either with the purpose to increase species diversity as such, and/or attract game species that can be hunted and give an economic return to the landowner. Moreover, during the last 20 years power-line ROWs, together with other linear infrastructure elements like roads, railways, fences and pipelines, have been subject to discussions weather they are barriers or semi-barriers creating avoidance effects to animals (e.g. Bevanger et al. 2005). It is now generally recognized and documented that human encroachments and disturbance may have adverse impacts on a wide range of mammals, birds and other organisms.

The fact that birds are killed by flying into power lines has made this a "field of tension" for naturalists and scientist for many years. In the same way as power lines ties up vast land areas, bird mortality due to power lines reflect both an ecological and economic problem. Birds being electrocuted may e.g. result in power outages and thus have an economic impact. The fact that several vulnerable and endangered bird species, as well as small game species are documented as common victims, gives the problem its ecological and conservational dimensions. Today, red-lists with updated knowledge on threatened species together with international obligations to stop the biodiversity loss, makes bird death due to electrocution or collision with power lines an obvious focal issue for energy as well as environmental managers.

The OPTIPOL rationale is based on the belief that the negative effects of electricity transmission and distribution can be reduced with respect to birds and mammals. The NINA scientists cover most of the applied ecological challenges faced. However, to develop effective mitigating measures, e.g. to reduce the number of birds colliding with the overhead wires or reduce the avoidance effect for ungulates require a close co-operation between ecologists and engineers, dealing with electricity transmission. Supporting structures for power lines and a diversity of specific constructions found within the Norwegian grid system must be considered carefully in order to safeguard the stability of energy supply to the consumer and/or violate safety regulations.

OPTIPOL has several ambitious objectives, and is divided into sub-projects and specific tasks described in the project application (Appendix 1). Due to budget cuts the use of radar technology had to be suspended, witch means that some of the other project objectives based on data collection from mobile-radar systems, have to be taken out of the project or heavily modified. We hope, however, it will be possible to raise money for this at a later stage.

2 Activities in 2009

2.1 Kick-off meeting in Trondheim April 23 2009

A one day project kick-off meeting was arranged in April (Appendix 2) where all subproject activities were presented by the responsible scientists, followed by discussions. Apart from the involved scientists, representatives for the users were present, i.e. Statnett (Pernille Ibsen Lervåg), EBL (Einar Wilhelmsen), NVE (Nils Henrik Johnsen) and DN (Lars Løfaldli). The County Governor in Nordland, responsible for executing the National Action Plan for the eagle owl, was also present (Mia M. Husdal). Representatives from OPTIPOL was also present on a one day work-shop focusing eagle owl in February (Appendix 3)

2.2 Meeting June 12 on ungulates and linear structures

In June a one day meeting was arranged in Trondheim focusing ungulates and linear infrastructure. The background for this meeting was the fact that there are several major projects in Norway, involving telemetry studies of reindeer (wild and domestic), moose and red deer. All these studies are based on the need for increased knowledge and understanding on how these species uses their living areas in space and time and respond to infrastructures, i.e. disturbance and encroachments, including linear structures like roads and power lines.

From NINA the following scientists were present: Kjetil Bevanger, Roel May, Christer Moe Rolandsen, Sigbjørn Stokke and Olav Strand. Moreover, Erling Meisingset from The Norwegian Institute for Agricultural and Environmental Research (Bioforsk) and Jonathan Colman from the Norwegian University of Life Sciences (Landbruksuniversitetet) attended. The minutes from the meeting is given in Appendix 4). It was agreed that OPTIPOL gives a unique opportunity to bring ungulate scientists together and look at data recorded in connection to a long range of projects in concert, and process otherwise partly resting data. The idea is that OPTIPOL may have space for a postdoc position (see 3.1.2) focusing how ungulates respond to linear structures. However, the project does not have resources to manage a postdoc alone, and need additional funding. Thus, NINA has sent a letter to the Norwegian Public Roads Administration (Vegdirektoratet) and the Norwegian National Rail Administration (Jernbaneverket) asking for a co-operation and economic support (Appendices 5 and 6).

2.3 PhD position

The project application included a 4 year PhD-position. The position was announced in several newspapers (Adresseavisen, Aftenposten, Teknisk Ukeblad), Jobb Norge as well as on the NINA and CEDREN Internet web pages (Appendix 7). The main objective of the PhD-activities is to assess how and why different wildlife species use deforested areas below power lines, evaluate possible positive and negative effects of power-line ROWs, and assess the possibilities for quality improvement. Among the 15 applicants Gundula Bartzke was selected and she started her work the first of November. She is formally a PhD-student at the University of Science and Technology (NTNU), but will have NINA as her main workplace.

2.4 Selection of research areas

The selection process for research sites has been delayed due to several reasons. On the April meeting NVE signalled that they could give authorised NINA personnel access to their power-line grid database. To have all formalities in place has been a long process, but on October 21 NINA got the message from NVE that the database-use agreement was ok, and on October 29 the database was transferred to our GIS experts.

On the outset the research areas are supposed to fulfil a number of criteria: e.g. cover power lines in the range of 22 – 400 kV, crossing different habitat types from lowland to alpine areas. They should be located in areas as close as possible to Trondheim, and they should be located within areas where running projects have radio collared ungulates (reindeer, moos, red deer).

We have now built a GIS model and are able to select sites based on specific criteria complying with the objectives of the subprojects; e.g. where do we find a specific power-line category within forested habitats and elevations from 250m-750m where the number of land owners are low, the distance from human infrastructure is low etc.

3 Subproject status and planned activities

3.1 Power-line rights-of-way (ROW) and wildlife

Subproject responsibility: Sigbjørn Stokke, Roel May, Gundula Bartzke, Kjetil Bevanger, Henrik Brøseth, Hans Chr. Pedersen, Eivin Røskaft

Objectives:

- Assess methods for transforming power-line ROW habitats into attractive habitats for birds and mammals and high quality wildlife biotopes.
- Assess bird and mammal movements along and across power-line corridors. Are power-line ROWs ecological corridors or barriers?
- Assess bird mortality due to collisions with power lines and identify topographic factors, including vegetation structure, trigging high collision risk.

The following research activities are planned to take place:

3.1.1 PhD project

Subtask responsibility: Gundula Bartzke, Sigbjørn Stokke, Kjetil Bevanger, Roel May, Hans Chr. Pedersen, Eivin Røskaft

Objectives:
Assess how and why different wildlife species use deforested areas below power lines, evaluate possible positive and negative effects of power-line ROW, and assess the possibilities for quality improvement.

3.1.1.1 Description of work

Habitat quality for many forest-related species can be improved by retaining structures allowing continued use in the power-line ROW. A challenge related to power-line clear-cut corridors in forested habitats is edge or ecotone effects. Edge effects related to silvicultural activities and other human-driven systems are poorly known for many species and this question applies in particular to the clear-cutting practice beneath the phase conductors. We therefore propose to assess the present value of power lines as wildlife biotopes and experimentally seek for treatment regimes of the extant vegetation to increase their value as attractive recourses for wildlife and hence make these areas more valuable for land owners.

Thus, the main objectives of this PhD is to assess how and why different wildlife species use power-line ROWs, evaluate possible positive and negative effects of power-line ROWs, and assess the possibilities for improving their quality as wildlife biotopes as such. The study will

- assess wildlife densities along and in the vicinity of power-line ROWs
- evaluate animal responses to power-line ROWs in relation to successional stages of vegetation in clear-cut corridors
- carry out experimental pruning of vegetation within power-line ROWs in order to find clear-cutting regimes having positive effects on wildlife

3.1.1.2 Research methods

- Estimate density of species along power-line ROWs and adjacent areas using Distance sampling
- Record animal behaviour by following tracks in the snow along power-line ROWs during winter time and stalking of radio-collared deer and possibly applying infrared video techniques during summer time
- GPS-collaring of gallinaceous birds (see also 3.1.3)

- Apply existing GPS relocations from radio-collared deer (moose, red deer, and wild and domestic reindeer; see also 3.1.2)
- Quantify vegetation in natural successional stages in clear-cut corridors below power-line ROWs
- Carry out experimental pruning of vegetation within power-line ROWs
- Apply capture-recapture techniques on small rodents along power-line ROWs

Several master students will be involved in the work. Three types of power-lines ROWs have been defined on which this subproject will focus: national high-tension routes (220-420 kV), regional high-tension routes (66-132 kV), and the distribution grid (22 kV). These three types represent three different levels of tension, and have contrasting differences in width of the ROW corridors. At the moment the exact locations of the study sites are decided upon.

3.1.2 Ungulate responses to linear structures (Postdoc project)

Subtask responsibility: Sigbjørn Stokke, Roel May

Objectives:
Assess the effects of linear structures on movement patterns and distribution in the landscape in native deer species. Within the scope of this project, we will examine how different spatial scales influence the processes that guide movement patterns, and responses to linear structures. This will be done by comparing different spatial responses to linear structures in functionally different species (wild and domestic reindeer, moose, red deer). This project has great relevance to elucidate the effects of linear structures on these species, and will provide advisory information for the adaptive management in minimizing detrimental fragmentation effects while maximizing traffic safety. The results can be implemented to direct mitigation measures along linear structures.

3.1.2.1 Description of work

Although many large ungulates are able to persist in multiple-use landscapes, they do possess characteristics making them vulnerable to habitat fragmentation due to infrastructure like roads, railways and power lines. Species-specific responses to linear structures are difficult to predict, due to differences in ecology, social systems and behaviour. The complex interactions between landscape and movement patterns must be studied at different spatial scales. Movement pattern analyses will be based on intensive GPS data (large high resolution datasets from moose, red deer and wild and domestic reindeer are available), to deduce species-specific behavioural responses that can be correlated with distance or cumulative effects of linear structures.

This makes it possible to analyse how the animals move relative to linear structures (e.g. power lines, fences, roads and railways) within different habitats and ecosystems. Moreover, by modelling the animal movement relative to roads and railways it is possible to identify high risk collision areas where ungulate crossings are likely to take place (based on the central register for ungulates and dead wildlife (hjorte- og fallviltregisteret)). By selecting on crossing time it is possible to predict collision high risk periods during the day. Moreover, it will be possible to identify seasonal variation and identify collision high risk habitats. It will also be possible to see how the movement patterns of the animals are modified by fences built along the roads and clear-cut areas to increase roadside visibility.

During this year the general framework of the proposed subproject has been set up and discussed with representative from the different GPS-projects during a meeting. This framework has been sent to the Norwegian Public Roads Administration (Statens Vegvesen) and the Norwegian National Rail Administration (Jernbaneverket) for possible additional funding. So far, the finances of this subproject are not in place, and will be further elaborated on next year.

Because this subproject may partly be financed through the OPTIPOL-project a start can be made on the organisation of data and preparation to the analyses.

3.1.2.2 Research methods

On-going projects on wild and domestic reindeer, moose, and red deer have over the last years built up unique data sets from GPS-collared individuals which are so intensive (one relocation per hour) that for the first time they can elucidate fine-scale movements of these wildlife species in contrasting landscapes (mountainous, forest, coastal and agricultural multiple-use landscapes). The main objective is to address six aspects important for rendering a better understanding of how linear structures influence species' movement patterns at different spatial scales and its applicability to transportation management, being:

1. **Behavioural responses**. Do the different species behaviourally respond to the proximity of (different types of) linear structures and at what response-distances do their movement patterns change?
2. **Cumulative effects**. Do the cumulative effects of parallel-placed linear structures have additive and/or compensatory effects on behavioural responses and response-distances in the different species?
3. **Boundary effects**. Do linear structures form important features for home-range delineation, and therefore affect each species' distribution in the landscape?
4. **Demographic effects**. Are the different species' behavioural responses, response distances and home-range delineations affected by demographic parameters such as population density, gender, age and season?
5. **Identification of hot-spots**. Can a species' movement pattern be used to identify hot-spots / high-risk areas for collisions along linear structures?
6. **Effectiveness of measures**. How do clearing regimes/mitigation measures (e.g. fences, vegetation removal) affect behavioural responses and response-distances and/or location and intensity of hot-spots?

3.1.3 Power-line corridors and small game species

Subtask responsibility: Henrik Brøseth, Kjetil Bevanger, Frank Hanssen, Roel May, Sigbjørn Stokke, Hans Chr. Pedersen, Gundula Bartzke, Ole Reitan, Roger Meås

Objectives:

1. Assess the impact of transforming ROW habitats into attractive foraging habitats for small game species (with mountain hare, capercaillie, black grouse and hazel grouse as model species).
2. Assess avoidance behaviour of gallinaceous birds towards power-line corridors (with capercaillie and hazel grouse as model species).
3. Assess mortality rates due to power-line collisions, relative to other human related mortality factors (primarily hunting) in gallinaceous birds (with capercaillie and black grouse as model species).

3.1.3.1 Description of work and research methods

1. Density estimation by distance sampling in three different ROW habitats (untreated, frequent cutting and ecotone) to test for differences in utilisation of different ROW habitats for foraging in autumn and winter/spring during a four year period. Supplementary quantify the availability of food such as berries (autumn forage) and twigs (winter forage). Distance sampling twice a year according to different forage (autumn and winter/spring)
2. Movement patterns of tetraonid species in relation to avoidance behaviour relative to power lines will be studied during a four year period by extensive use of radio telemetry

using both continuous GPS-logging (capercaillie) and traditional VHF-transmitters (hazel grouse).

3. In an intensively studied area (30-50 km^2) we will over a four year period census the population of capercaillie and black grouse by transect sampling of droppings for DNA identification in winter/spring and lek counts. Simultaneously, power lines in the area will be searched for dead birds killed by flying into the overhead wires using special trained dogs. By DNA identification of the dead birds (collisions victims and hunted birds) we will get estimates of different human related mortality rates in the population. Annual survival estimates from the capture-recapture DNA-design will be used to compare the risk of collision mortality relative to distance to power lines.

3.1.4 Mortality studies

Subtask responsibility: Henrik Brøseth, Kjetil Bevanger, Frank Hanssen, Pål Kvaløy, Hans Chr. Pedersen, Gundula Bartzke, Ole Reitan, Roger Meås

Objectives

The overall objective for this subproject is to assess bird mortality due to collisions with power lines and identify topographic factors, including vegetation structure, trigging high collision risk.

3.1.4.1 Description of work and research methods

Gallinaceous birds together with some other species groups are proved to be over-represented among power-line collision victims (Bevanger 1998). Searches for injured or dead victims in or near power lines are necessary to assess the number of victims and estimating species-specific collision risks, together with mortality extent and population impact. Moreover, to be able to identify topographic and external factors that influence the collision-risk factors, it is necessary to have detailed information on the place where collisions take place. This problem is addressed through several subprojects in OPTIPOL. Available data as well as new data will be the basement for modelling how birds use the terrain and thus enable – by means of GIS-tools - to predict what topographic structures and habitats that should be avoided when new power lines are routed.

The main method used to find power-line collision victims is criss-crossing patrols beneath the phase conductors in the clear-cut corridor. To be efficient in the effort to find dead birds searches have to be accompanied by a special trained dog. These are dogs trained to have a search image of groups of feathers and dead birds, and they will show the dog handler where there is a bird or remains of a bird. In NINA one dog – a riesenschnauzer, so far is especially trained for this (Luna, owner Ole Reitan) and used at both wind turbines and power lines. A new dog is recently bought and the training has started. This is a wachtelhund, born in September 2009 (owner Roger Meås).

Although the search regime has to be adapted to the local conditions, there are several factors to be aware of when dead bird searches are carried out. Local ‘bias tests’ designed and fitted to specific conditions and target species are needed to obtain corrections that would be broadly accepted regarding the extent of mortality. The main variables connected with counts of dead birds can be divided into three categories; performance, site-specific and object variables (Bevanger 1999).

Performance variables include factors connected with the number of participating field workers (including dogs), the personal skill and experience of the field workers, and how the patrol is conducted, i.e. the search pattern and time used, but also the external conditions. Site-specific variables and habitat bias is connected to local conditions (geographical, topographical, meteorological, technical, faunistical and vegetational), and are always crucial for the validity and reliability of data on mortality caused by power lines. However, in general, what is called the habitat bias is considered to be the most important site-specific variable.

A particularly important site-specific variable is the removal of collision victims by scavengers. To minimise the effect of scavengers, the search regime will be adjusted to local conditions based on knowledge of scavenger species and their life-history patterns. The size of the victims and the scavenger species present are additional important factors for the removal pattern and the probability that the patroller and the dog will discover remains of collision victims or other evidence revealing that a collision has occurred. "Small" birds like willow ptarmigan can e.g. be expected to have a faster turnover than larger ones such as capercaillie which is not easily removed by scavengers without leaving feather remains. Birds may also sustain injuries in strikes which are not immediately fatal, allowing them to continue flying (or walking) for some distance making them hard to find during patrols, despite the use of highly trained bird dogs. In order to obtain information on scavenger removal bias, cameras will be located at bird carcasses as well.

3.2 National infrastructure for management of dead-bird data

Subproject responsibility: Pål Kvaløy, Roald Vang, Kjetil Bevanger, Henrik Brøseth, Ole Reitan

Objectives:
Establish a national infrastructure for management of dead-bird data (including birds recorded as collision and electrocution victims).

3.2.1 Description of work

- Develop and implement a SQL-server spatial database for dead-bird data
- Import existing bird-collision data from various projects in NINA. Develop an online web application for registering bird collisions via Internet to target as many relevant users as possible
- Identify species- and site-specific factors regarding bird collisions along power-lines

3.2.2 Research methods

The database and web application will be developed by NINA and made public available for a wide range of users.

3.2.3 Activities and findings

A functional database is established at NINA. The database supports spatial analysis and queries. Some bird-collision data in spreadsheet format from recent projects have been examined to determine a data structure which facilitates import.

It is developed a functional prototype of the web application for registering dead birds (Figure 1). It incorporates topographical maps, and also has the possibility of overlaying power-line maps. Some geocoding conversion functions are incorporated. It is possible to upload pictures of collided/dead birds.

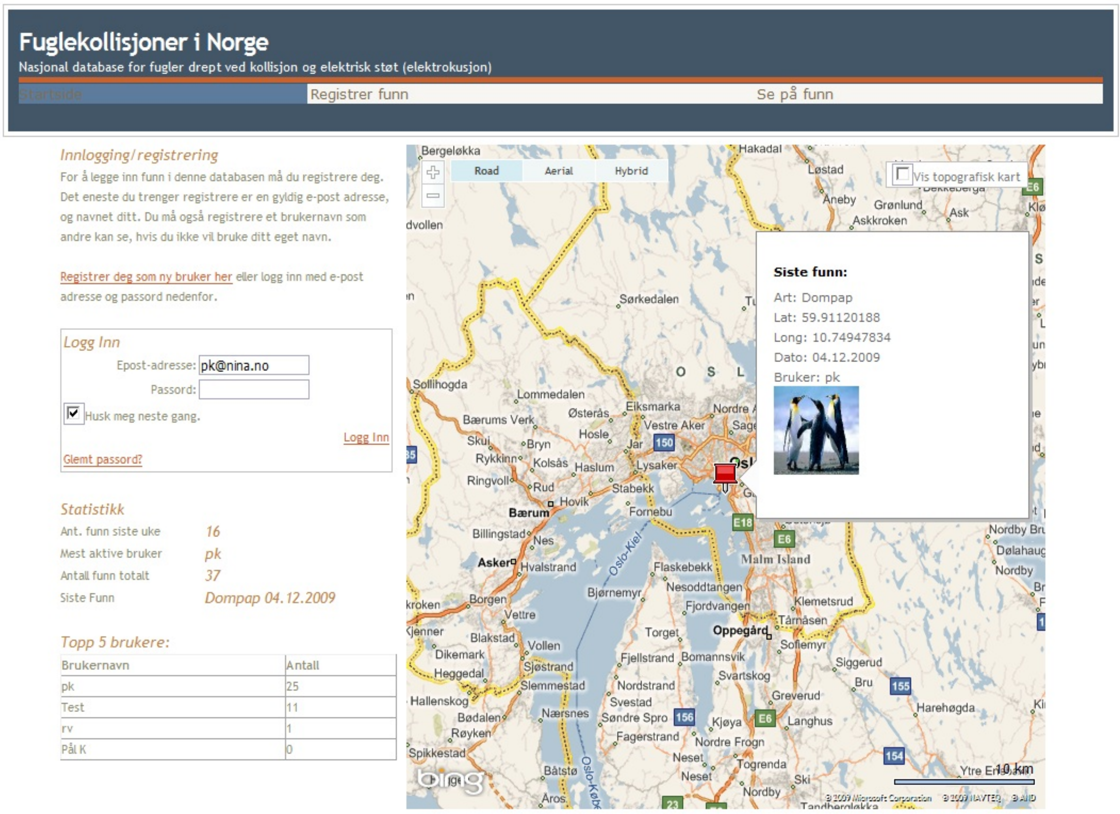

Figure 1. *Screenshot of the web application for registration of recorded dead birds.*

3.2.4 Work to do

- Refine the web application and the underlying database
- Get a scheduled export from Artsdatabanken (http://artsobservasjoner.no/fugler) with data of dead birds
- Import collision data from various spreadsheets and projects in NINA
- Target as many relevant users as possible

3.3 A Least Cost Path (LCP) toolbox for optimal routing of power lines

Subproject responsibility: Frank Hanssen, Roel May

Objectives:

- Identify ecological high-risk areas for bird collisions using the national dead-bird database, field observations and advanced statistical/GIS-modelling.
- Develop a LCP-desktop GIS toolbox for optimal routing of power lines based on ecological, financial and technological criteria.

3.3.1 Description of work

The GIS- toolbox for optimal routing of new power lines will implement least-cost path (LCP) methodology to locate the most optimal routing based on economical, technological and ecological criteria. The economical and technological criteria, and how these translate to the landscape, will be identified together with Statnett and NVE. The ecological criteria will be identified by experts from NINA, our research networks and existing knowledge. Methodology for calibration of all criteria and their individual weights will be applied into the toolbox. The spatial component of all these criteria and other relevant criteria will together with the ecological high risk areas map form the basis of the least-cost path analysis.

The LCP-toolbox will aid decision makers in determining future routing of new power lines, and help in identifying high-risk segments with possibilities for rerouting or technically modifying power-line structures.

3.3.2 Research methods

- Literature review
- GIS-terrain modelling
- Statistical-prediction modelling
- LCP-methodology

3.3.3 Activities and findings

A pilot LCP-GIS-toolbox has been developed and will be further elaborated during 2010.

Data from the national power-line database from NVE has been organised for internal use in a restricted/classified database at NINA. This data is used together with ecological background data to identify case study areas.

In 2010 we will further develop the LCP-GIS-toolbox implementing calibration and classification of all criteria, and their individual weights, and applied in case study areas. Relevant map layers, their classification and their individual weights will be identified in open-dialogue discussions with all relevant stakeholders.

Else, we will identify ecological high-risk areas for bird collisions using the national bird collision database, field observations and advanced statistical/GIS-modelling.

3.4 Mobile radar systems

Subproject responsibility: Roel May, Yngve Steinheim

Objectives:

- Identify bird hot-spots and high-risk areas for bird collisions using mobile radar technology and advanced GIS terrain modelling.
- Identify increased collision risk contributing factors for birds flying into power lines, and test the effectiveness of mitigating measures such as camouflaging and bird diverters.

This sub-project is temporarily suspended.

3.5 Power-line camouflaging

Subproject responsibility: Kjetil Bevanger, Steinar Refsnæs, Olle Håstad

Objectives:

- Review available literature to assess weather camouflaging techniques is to be recommended given the present knowledge on bird vision
- Review technical properties and constraints of camouflaging techniques on conductors and earth wires

3.5.1 Description of work

Assess power-line camouflaging techniques and assessment of effectiveness relative to present knowledge on bird vision

3.5.2 Research methods

Literature review.

3.6 Mitigating bird collisions and electrocution

Subproject responsibility: Kjetil Bevanger, Jan Ove Gjershaug, Steinar Refsnæs

Objectives:

- Review available literature on technical modifying solutions and assess their effectiveness to mitigate bird collisions and electrocution.

3.6.1 Description of work

- Assess the effectiveness of reducing bird mortality by conductor marking equipment
- Assess the effectiveness of design methods and modifications to reduce electrocution hazard for birds
- Where and when are earth cabling and other technical alternatives to mitigate bird collisions with overhead wires justified from an ornithological point of view

3.6.2 Research methods

Literature review.

3.7 Guidelines for technical solutions to mitigate bird collisions and electrocution hazard

Subproject responsibility: Steinar Refsnæs, Kjetil Bevanger, Jan Ove Gjershaug

Objectives:

- Determine the technical properties of conductor marking equipment.
- Establish cost effective line design modifications to mitigate bird strikes or electrocution hazard.
- Evaluate when and where underground (earth) cabling will be a technical and economic solution to mitigate bird strikes.
- Consider actual insulating cover techniques on preferred poles associated with bird electrocution
- Guidelines for technical solutions to mitigate bird strikes or electrocution hazard.

3.7.1 Description of work

Conductor marking equipment physically enlarges the wires may e.g. act as wind-catching objects, encouraging icing in winter and increasing the risk of wire breakage and outage of power supply due to line tension and stress loads.

State of the art in how structures connected to energy production and supply should be designed or modified in order to minimize electrocution hazard. Although a significant job has been made in several countries to develop alternative constructions both to mitigate bird electrocution as well as collisions, these solutions may not be suitable for the environmental conditions we have in Norway. Actual line design modifications to consider are support- or suspension insulators, pole mounted transformers, elevated perch constructions, change critical distances between phase-phase or phase-ground.

The main questions to be asked in relation to underground cables (UGC) are where and when are underground cabling and other technical alternatives a solution to mitigate bird strikes?

Actual insulating cover techniques to consider on preferred poles are e.g. insulated phase conductors, insulated cross arms and caps on support insulators).

NVE recently delivered a report (Johnson 2008) to the Ministry of Oil and Energy suggesting supporting structures as well as the phase conductors to be painted in green.). Unfortunately, camouflaging power lines could give unwanted effects with respect to increased bird collision hazard, depending on how birds perceive a coloured wire. Some of the techniques may also cause physical damage through corrosion on the conductors.

3.7.1.1 Marking

- Literature review of conductor marking equipment
- Ageing tests on conductor marking equipment
- Mitigating properties of marking equipment and their effect on OHL-equipment

3.7.1.2 Design

- Literature review of design methods
- Design or modification in order to minimize electrocution hazard

3.7.1.3 Insulating

- Literature review of insulating cover techniques
- Find suitable locations and establish testing of the mitigating properties of insulating cover techniques and their effect on OHL-equipment
- Accelerated corrosion tests on OHTL equipment covered by insulating cover techniques
- Voltage withstand tests on OHTL equipment covered by insulating cover techniques
- Mitigating properties of insulating cover techniques and their effect on OHL-equipment

3.7.1.4 Camouflaging

- Literature review of camouflaging techniques
- Ageing tests on camouflaging conductors
- Camouflaging techniques and their effect on conductors

3.7.1.5 Cabling

- Literature review of actual cable design; 10 kV-72 kV (aerial / underground cable, UGC)
- Survey of failure rates of underground cable (UGC) and overhead lines (OHL)
- Voltage build-up in cables inserted in an OHL
- The issues of costs that are fundamental when it comes to comparing OHL and UGC
- Are the utilities able to ensure effective maintenance on mixed lines?
- Mitigating properties of cable down lead to ground transformers
- Where and when are earth cabling and other technical alternatives a solution to mitigate bird strikes
- Mitigate bird electrocution as well as collisions, technical solutions

3.7.2 Research methods

- Literature reviews
- Comparative field studies in Lurøy by testing actual insulating cover techniques. Old conductors have to be replaced by new conductors in advance of the test period. The expenditures must be considered as a special topic.
- Field experiments regarding conductor marking equipment.

- Laboratory experiments, (i.e. tests on camouflaging conductors and conductor marking equipment)

3.8 Eagle Owl

Subproject responsibility: Jan Ove Gjershaug, Karl-Otto Jacobsen, Torgeir Nygård, Kjetil Bevanger

Objectives:
Assess eagle owl mortality caused by power-line collision and electrocution, and identify high-hazard structures.

Photo 1. *The Eagle owl has status as endangered on the Norwegian Red List.* Photo: Jan Ove Gjershaug.

3.8.1 Description of work

The Norwegian eagle owl population has experienced a steep decline since the 1950ies. The number of breeding pairs is now estimated to be something between 408-658 (Jacobsen et al. 2008), but a major national survey in 2008 revealed confirmed breeding in only 59 territories, while birds were present at 271 (Øien et al. 2009). The species is categorised as endangered (ED) on the Norwegian Red List (Gjershaug et al. 2006). The most important mortality factor for the species, and possibly the main reason for the population decline, is electrocution (Bevanger & Overskaug 1998). Based on input from NINA, the authorities launched a national action plan in 2009 for the species (Direktoratet for naturforvaltning 2009). The responsibility for the following up of this plan is given to the County Governor in Nordland.

In 2008 NINA initiated a pilot study on power lines and eagle owl on Solværøyene/Sleneset in the municipality of Lurøy in the county of Nordland, a study funded by the Directorate for Nature Management (Gjershaug & Jacobsen 2008). Our study area contains approximately 25 pairs of eagle owls, and the whole municipality of Lurøy has probably 40-50 pairs of eagle owls in good periods, which probably makes this the most suitable study area for eagle owls in Norway. Over the last twenty years members of the Rana Zoological Society have recorded 30-40 dead eagle owls in connection to utility structures, and about 90% of the specimens were killed by electrocution, the rest by collisions (Espen R. Dahl pers. comm.). This makes the area suitable for e.g. mitigation experiments.

3.8.2 Research methods

The study will use the following approaches:

1) Use of GPS satellite telemetry to investigate to what extent the eagle owls uses the pylons during hunting activities
2) Use of GPS satellite telemetry to map movements of and find electrocuted eagle owls
3) Collecting feathers of eagle owls from the nests for DNA analysis to get a mortality estimate for adults.
4) Searches beneath all power lines and pylons in the study area to find carcasses of eagle owls and other birds.
5) Investigate the breeding success of the eagle owls and evaluate how the mortality of adult birds affects the breeding success.

3.8.3 Activities and findings

In 2009 3 adult and 4 juvenile eagle owls were equipped with GPS-radio transmitters (Photo 2). The first two adult birds were females. They both succeeded to remove the transmitters after one week by biting off the teflon bands that attach the transmitters to the back of the birds. This was unexpected, since prior experience with eagles has not shown this to be a problem. The transmitters were later found by tracking of their signals, and were reused on two other birds. One of these birds was the adult male in the same pair as one of the females. This time we used a thin nylon wire inside the teflone band to make it stronger. The male gave signals in one week before the signals disappeared, probably due to lack of charging of the solar panel batteries. The results from one week of data from the male and female in the same pair are shown in Figure 2. Two of the four juvenile eagle owls with transmitters were found dead in the nesting area. A third bird left the nesting area and visited other islands before the signal disappeared. The fourth juvenile left Solværøyene and gave signals from the island of Lovund and nearby islands before transmitting ceased in November (Figure 3).

Eagle owl feathers for future DNA analyses have been sampled. Searches were carried out beneath all power lines and pylons in the study area to find carcasses of eagle owls and other birds. Old bones from two eagle owls and three sea eagles were found beneath pylons, i.e. electrocuted birds. They have all been overlooked last year because there was much more vegetation in July, when the last year's investigations were carried out.

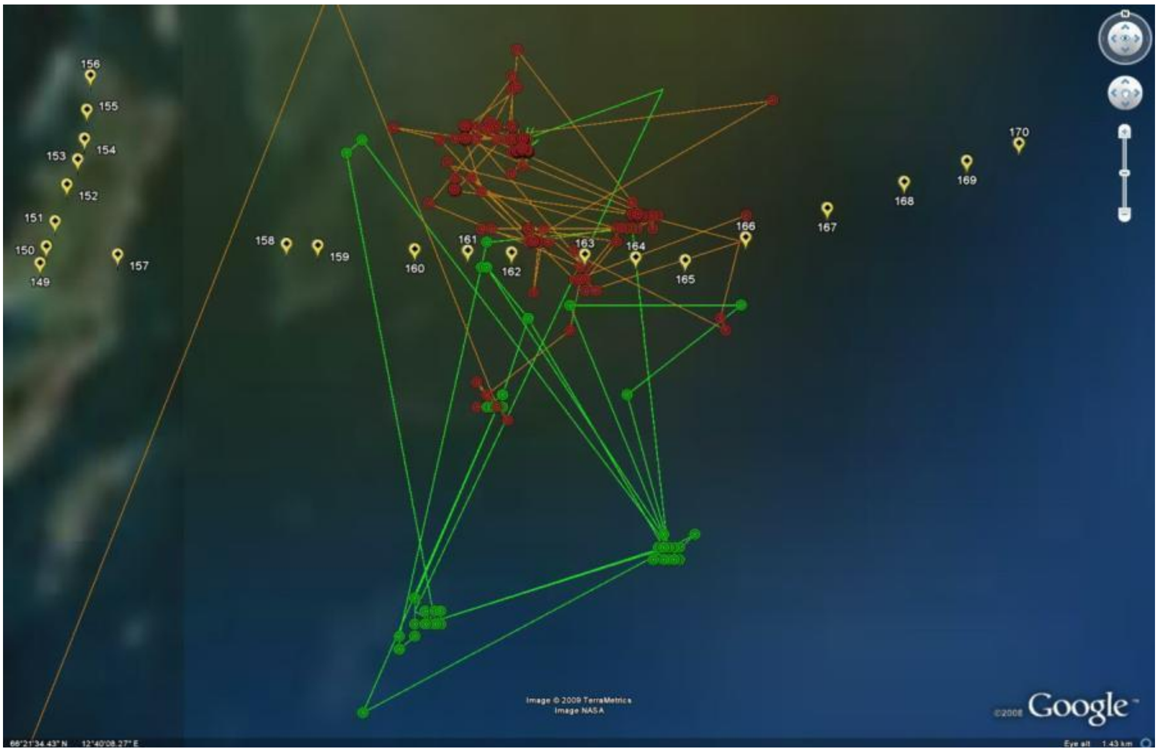

Figure 2. *Movements of an eagle owl pair (female in red 14-18 June, male in green 17-21 July) in relation to a power line (pylons in yellow).*

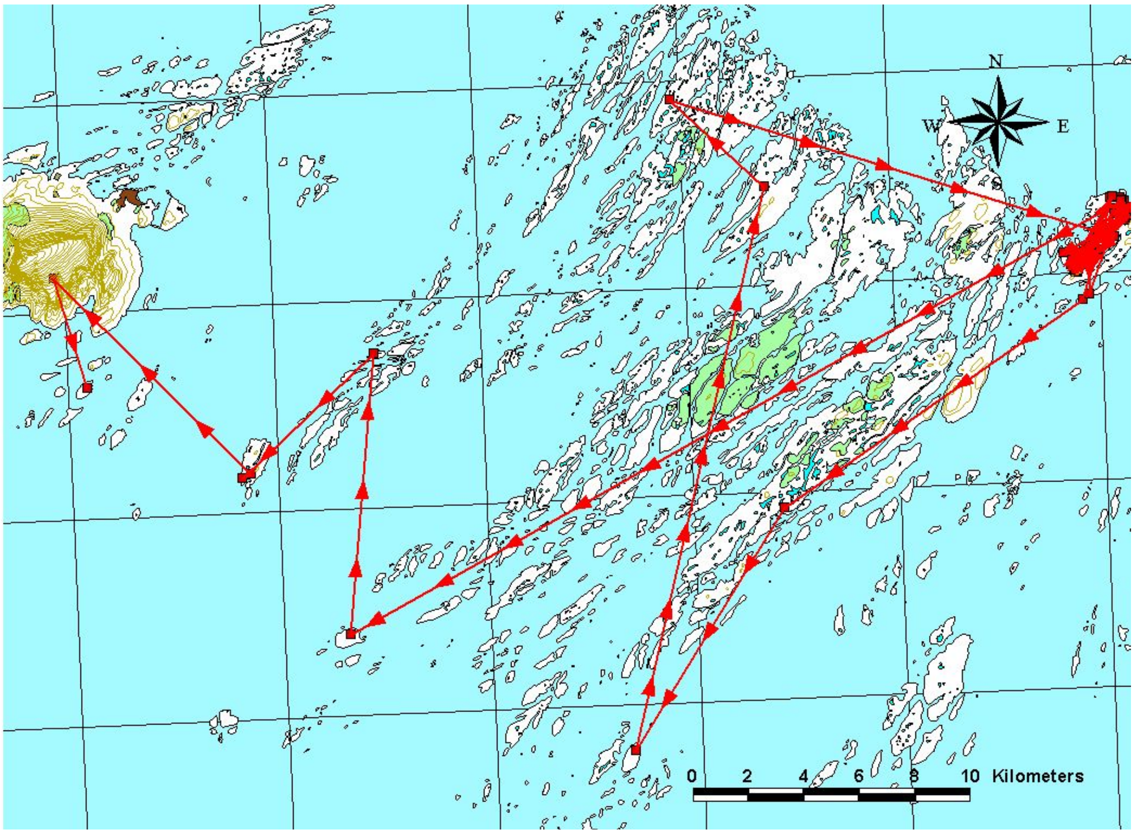

Figure 3. *Movements of a juvenile eagle owl before transmitting ceased in November 2009*.

Photo 2. *Eagle-owl male equipped with radio transmitter.* Photo: Jan Ove Gjershaug.

Photo 3. *Eagle owl resting on a crossarm with top insulators of a 22-kW power line on Sleneset, Nordland County. A highly unsafe position for the bird*. Photo: Jan Ove Gjershaug.

4 Publications, lectures, coverage in public media and conference participation related to the project

4.1 Publications

4.2 Lectures and conference participation

Bevanger, K. 2008. *Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway* og *Optimal design and routing of power lines; ecological, technical and economic perspectives*. Foredrag på intern FoU-dag i NVE (KTE/KTN) 9. desember, Oslo.

Bevanger, K. 2009. Fugl og kraftledninger - en kunnskapsstatus. Foredrag på FoU-seminar i Statnett 15.01., Oslo.

Bevanger, K. 2009. Vindkraft, kraftledninger og fugl – en kunnskapsstatus. Foredrag på workshop om vindkraft, kraftledninger og hubro, 24. februar 2009, Trondheim. Arrangør NVE og DN.

Bevanger, K. 2009. BirdWind and OPTIPOL. Kick-off seminar CEDREN 29.09., Trondheim. Kick-off møte OPTIPOL. 23.04.2009, Trondheim.

Bevanger, K. 2009. Overordnede målsettinger i OPTIPOL og relasjoner til CEDREN.

Bevanger, K. 2009. Utfordringer ved bruk av fargekamuflering og merkemetoder på kraftledninger.Hvilke arter bør fokuseres i forhold til kollisjonsproblematikk; metodikk og prosjektdesign. Kick-off møte OPTIPOL. 23.04.2009, Trondheim.

Gjershaug, J.O. Hva trenger vi av ny kunnskap for å identifisere/verifisere kritiske strukturer i lednigsnettet; tiltakenes prioriteringsrekkefølge. Kick-off møte OPTIPOL. 23.04.2009, Trondheim.

Jacobsen, K.-O. 2009. Biologi og bestandsstatus hos hubro. Foredrag på workshop om vindkraft, kraftledninger og hubro, 24. februar 2009, Trondheim. Arrangør NVE og DN.

May, R. 2009. Fugl på linja. Identifisering av “hot-spots” vha radar og optimalt trasévalg av kraftledninger. Kick-off møte OPTIPOL. 23.04.2009, Trondheim.

May, R. & Hanssen, F. 2009. OPTIPOL - optimalt trasévalg av kraftledninger. Møte Statnett/NVE. 24.06.2009, Oslo

May, R., Stokke, S. & Bevanger, K. 2009. Optimal design and routing of power lines; ecological, technical and economic perspectives. Hjortevilt og lineære strukturer. Møte om GPS samarbeid. 12.06.2009, Trondheim.

Refsnæs, S. 2009. Teknisk design og løsninger som reduserer faren for fuglekollisjoner eller elektrokusjon; muligheter og tekniske begrensninger. Kick-off møte OPTIPOL. 23.04.2009, Trondheim.

Stokke, S. & May, R. 2009. Power line rights-of-way (ROW) as wildlife biotopes. Kick-off møte OPTIPOL. 23.04.2009, Trondheim.

Vang, R. Nasjonal database for registrering av fugl drept pga. Kollisjon/elektrokusjon. Kick-off møte OPTIPOL. 23.04.2009, Trondheim.

4.3 Coverage in public media

Aftenposten – 15.10.2009. Tar mer ryper enn jegerne. Kjetil Bevanger.

Jakt & Fiske 16.10.2009. Rypas største trussel. Kjetil Bevanger.

Norges Jeger- og Fiskerforbund – 26.10.2009. Jakt med elektrisk spenning. Kjetil Bevanger.

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Bevanger, K. 1999. Estimating bird mortality caused by collision with power lines and electrocution; a review of methodology. – Pp. 29-56 in Ferrer, M. & Janss, G.F.E. (eds.). Birds and power lines. Collision, electrocution and breeding. Querqus.

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Gjershaug, J.O., Kålås, J.A., Lifjeld, J., Strann, K.-B., Strøm, H. & Thingstad, P.G. 2006. Fugler *Aves*. S. 355-363 i Kålås, J.A., Viken, Å. & Bakken, T. (red.). Norsk Rødliste 2006 – 2006 Norwegian Red List. Artsdatabanken, Norge.

Jacobsen, K.-O. & Røv, N. 2007. Hubro på Sleneset og vindkraft. *NINA Report* 264. 33 pp.

Jacobsen, K.-O., Øien, I.J., Steen, O.F., Oddane, B. & Røv, N. 2008. Hubroens bestandsstatus i Norge. Vår Fuglefauna 31: 150-158.

Øien, I.J., Steen, O.F., Jacobsen, K.-O. & Oddane, B. 2009. Hubroen i Norge: Resultater fra nasjonal kartlegging i 2008. – Vår Fuglefauna 32: 150-156.

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6 Appendices

Appendix 1. *Project application to NFR as of June 4 2008.*

Optimal design and routing of power lines; ecological, technical and economic perspectives

A project proposal to the Norwegian Research Council, 4 June 2008

Active partners

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PART 1: The KMB project

1 Objectives

Develop predicting tools for optimal routing of power lines from an environmental perspective and assess technical and economic solutions to minimize conflicts with wildlife and habitat conservation.

Subgoals

- Establish a national infrastructure for management of bird-collision data.
- Identify bird hot-spots and high-risk areas for bird collisions using mobile radar technology and advanced GIS terrain modelling.
- Build a least-cost path GIS-based application for optimal routing of power lines based on ecological, technical and economic criteria.
- Produce guidelines on how to transform power line rights-of-way into high quality wildlife biotopes.
- Assess bird and bat migration along power lines using mobile radar technology. Are power line rights-of-way: ecological corridors or barriers?
- Assess power-line visibility. Is it possible to increase human acceptance by camouflaging power lines without increasing bird death toll, or increase power-line visibility to mitigate bird-strike hazard without compromising aesthetic standards?
- Produce guidelines for technical solutions to mitigate bird strikes or electrocution hazard. Where and when are earth cabling and other technical alternatives a solution?

2 Frontiers of knowledge and technology

Environmental as well as economic and aesthetic impacts of overhead wires and power-line corridors have been discussed world-wide for decades. The “First National Symposium on Environmental Concerns in Rights-of-Way Management” was e.g. held in Mississippi back in 1976 (Tilman 1976), the ninth symposium will take place in 2009 (http://wwaw.rights-of-way-env.com/index.htm). A frequent focus on birds and wildlife is reflecting both the ecological and economic importance of the problems; birds being electrocuted may e.g. result in power outages and thus have an economic impact. The fact that several vulnerable and endangered bird species, as well as small game species was documented as common victims (cf. review in Bevanger 1994a), gave the problem its ecological and conservational dimension. Today, red lists with updated knowledge on threatened species together with international obligations to stop the biodiversity loss, make bird death due to electrocution or collision with power lines an obvious focal issue for energy as well as environmental managers.

Another focus of attention is the power-line corridors, which constitute an economic problem tying up huge land areas e.g. for the forestry sector. At the same time they constitute a specific habitat type which could benefit some species while others may suffer. Moreover, during the last 20 years power-line rights-of-way together with other linear infrastructure elements like roads, railways, fences and pipelines have been subject to discussions weather they are barriers or semi-barriers creating avoidance effects to animals. It is now recognized and documented that human encroachments and disturbance may have adverse impact on a wide range of mammals, birds and other wildlife species (Gill et al. 1996, Gill & Sutherland 2000, Frid & Dill 2002, Clevenger & Waltho 2005).

Collision problems regarding birds and overhead power lines are basically quite simple and connected to the fact that birds need free airspace for performing a normal life. Electrocution hazards could be significantly mitigated by design modifications of supporting structures of high tension power lines up to about 130 kV as well as for low voltage distribution. However, environmental and technical challenges connected to energy distribution, are frequently site and species specific, depending on a range of factors relating to environmental conditions as well as climatic, topographic and other non-biological issues. Thus a search for universal solutions to mitigate or remove all conflicts related to these issues is not a realistic approach due to the complexity of both the biological as well as the technical problem (review in Bevanger 1994a). Also the development of effective site specific mitigating measures necessitates identification of intricate cause/effect relationships and target species.

A steadily increasing environmental stress has made mortality factors important that once were considered insignificant and thought to be compensated for among the survivors. Thus, the cumulative impact of additional mortality from electrocution, collisions with power lines, wind turbines, telegraph wires, ski lift wires, fences, windows, lighthouses, cars, aircrafts, trains etc. should not be dismissed as trivial (Baines & Andrew 2003, Barrios & Rodríguez 2004, Bevanger 1994a, Bevanger & Brøseth 2000, 2001, 2004, Ogden 1996, Pedersen et al. 2004, Watson & Moss 2004).
“Not in my backyard” is a term commonly used to describe local opposition to projects giving some auditive or visual “pollution” like power lines or wind power turbines. The idea of “camouflaging” power lines through paint coating is probably reflecting the opposition to power lines as a visual polluting element and has been an issue for several years (e.g. Statnett 1998). Unfortunately environmental and aesthetic considerations are commonly mixed into something which politicians may consider as a good solution, while an ecologist often identifies new ecological problems being generated. Power lines as well as the supporting structures can be made less visible to humans by using paint and colours matching the background, thus reducing the visual impact or “pollution”. NVE recently delivered a report (Johnson 2008) to the Ministry of Oil and Energy suggesting supporting structures as well as the phase conductors to be painted in green. It is reported that the response from the minister was positive (http://www.tu.no/energi/article140362.ece). Unfortunately, camouflaging power lines could give unwanted effects with respect to increased bird-collision hazard, depending on how birds perceive a coloured wire (Bevanger 1999b).

There are several technical issues related to birds and energy transmission, e.g. how should structures connected to energy production and supply be designed and constructed to minimize electrocution hazard. Engineers, in cooperation with ecologists, have a good record in identifying electrocution high-risk areas and modifying electrical equipment to avoid or reduce the electrocution of birds (Ohlendorff et al. 1981, APLIC 2006, Lehman et al. 2007). Unfortunately, adoption and implementation of identified solutions has only been done to a limited extent in Norway, in spite of the fact that a particular concern about the electrocution and collision hazard to birds has been raised by the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) (Resolution 7.4 – Electrocution of migratory birds) and the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) (cf. Recommendation No. 110) (Bern Convention 2004). Both the Bonn and Bern Convention are adopted by Norway. Recommendation No. 110 includes guidelines for a variety of remedial actions to be taken.

One of the species frequently in focus in Norway is the eagle owl, a red-listed species which is known to be electrocuted frequently in connection to e.g. pole mounted transformers (Larsen & Stensrud 1988, Bevanger & Overskaug 1998). The same problem is recorded elsewhere in Europe (Stolt et al. 1986, Haas 1980, Lehman et al. 2007). The eagle owl mortality connected to pole mounted transformers is supposed to be mitigated by adequate remedial actions (Lindgren 1984).
It is also possible to modify the design of power lines to reduce the collision hazard. Although a significant job has been made in several countries to develop alternative constructions both to mitigate bird electrocution as well as collisions these solutions may not be suitable for the environmental conditions we have in Norway. Wire marking which physically enlarge the wires may e.g. act as wind-catching objects, encouraging icing in winter and increasing the risk of wire breakage and outage of power supply due to line tension and stress loads. The attachment of devices may also cause physical damage through abrasion to the conductors. Neither optimal corridor location nor phase-conductor marking completely remove the collision problem, thus there is one reliable method left - underground cabling. The main argument against underground cables is their cost (e.g. Madsen 1979, Thompson 1978, Longridge 1986).

3 Research tasks

The overall aim of this project is to take the focal issues related to wildlife and energy distribution a step forward by addressing new technical solutions for practical and sound economic mitigating measures, newly developed avian radar technology and advanced GIS-analyses techniques. The complex nature of the problems involved necessitates a team of scientists with complementary knowledge within technological and ecological issues working closely together. The research questions relating to power lines and wildlife illustrates the need for basic knowledge on a variety of biological and ecological factors, in particular those related to species-specific life history and behavioural ecology, morphology, biomechanics and physiology. A PhD-student and master students from e.g. NTNU will be connected to the project. The focus of the research tasks are subdivided into the following topics:

A Identify bird hot-spots and high-risk areas for bird collisions using mobile radar technology and advanced GIS terrain modelling

The objectives of this part are to identify which factors contribute to an increased risk of collision between birds and power lines. Flying behaviour, and consequent susceptibility to power lines, is affected not only by species (e.g. wing morphology, life-history strategies), but also by topography and habitat, weather conditions, season and lighting (Bevanger 1998). Birds are expected to adjust their flight path according to the hierarchical spatial distribution of requirements such as food resources, nest and resting sites and environmental factors (Boyce 2006). Understanding flying behaviour therefore requires the detection of changes in flight path characteristics across scales (Fritz *et al.* 2003) for identifying high-risk areas for collisions. Baseline data on bird collisions with power lines have been collected extensively in Norway during 1984-1995 (Bevanger 1994a, b, 1998, 1999; Bevanger & Brøseth 2001, 2004). Locations of these bird collisions, together with habitat characteristics along power lines, allow us to identify areas with high collision risk giving insight into high-risk areas with high *absolute* number of collisions irrespective of bird activity. It is, however, also of importance to identify areas of high bird activity (bird hot-spots); and relate collision numbers to activity (i.e. *relative* collision rates).

B Build a least-cost path GIS-based application for optimal routing of power lines based on ecological, technical and economic criteria

The objectives of this part are to build a practical GIS-based application to find the optimal routing for new power lines. The application will use least-cost path methodology to locate the most optimal routing based on economic, technical and ecological criteria. The economic and technical criteria, and how these translate to the landscape, will be identified together with Statnett and NVE. The spatial component of these criteria, together with the ecological high-risk areas map, and possibly other ecological or other criteria (e.g. reindeer grazing areas, cultural monuments, land ownership) will form the basis of the least-cost path analysis. The application will be able to calculate the optimal route based on the start/end point for a future route. It can also indicate the “cost” existing power lines have at the moment; and give possible alternatives with less impact on birdlife and other wildlife. The foreseen application will be a tool to aid decision makers in determining future routing of new power lines, and help in identifying high-risk segments with possibilities for rerouting or technically modifying power-line structures.

C Power line rights-of-way (ROW) as wildlife biotopes
The objectives of this part are to assess how and why different wildlife species are using power-line ROWs, evaluate possible positive and negative ecological effects of power-line ROWs, and assess the possibilities for improving their quality as wildlife biotopes. Certain treatments of the vegetation below power-line ROWs may particularly attract more ungulates, acting as a "pruning team", and thus reducing clear cutting costs. At present there is more than 200 000 km of power lines (Statistisk sentralbyrå 2007) in Norway. As all vegetation below them are cleared at various widths these clear-cuts represent large areas in mostly forested areas. Most land owners regard these areas as rather useless and unproductive (Sagen 2007). Thus it is important to assess the possibilities for optimizing the use of these areas both from an ecologically and technologically point of view. We plan to incorporate a PhD student in this part of the project.

D Camouflaging power lines and power-line structures
The objectives of this part are to assess the possibilities for increased collision hazard to birds by making the power-line structures less visible for humans. To achieve optimal detectability of a power line for birds it is important to carefully consider and optimize the contrast of the wires against the background. However, this could impose another problem as visual "pollution" and aesthetic concerns have become a topic to many people. Bird survival is strongly affected by their visual capacities and bird eyes are highly specialized instruments, with a visual acuity 2-8 times higher than a mammalian eye. Moreover, birds have highly developed colour vision. Birds see more colours than humans, and it is generally believed that the colours appear more saturated than they do to us. The reason is that birds have four cone types involved in colour detection, and pigmented oil droplets in these photo receptors. While humans have short, middle and long (also called blue, green and red) cones, birds also have a ultra-violet- (UV) cone with a UV-perception from 320 nm (e.g. Martin 1990, Butler 1996, McIlwain 1996, Valberg 1998). Thus camouflaging power lines with the intention to make them less visible to humans includes several unanswered questions related to how this should be done without increasing the collision hazard to birds. However, Osorio et al. (1999) found that the ability of birds to distinguish between colours in the yellow range of the spectrum probably surpasses that of humans. It seems likely that some green and yellow colours, especially if they have a strong UV contribution will contrast greatly against a natural green background for birds while a human observer would find the same colour much less conspicuous.

E Guidelines for technical solutions to mitigate bird strikes or electrocution hazard
The objectives of this part are to assess technical modifying solutions and their economic costs to mitigate bird collisions and electrocution. A goal is to establish cost-effective line design modifications to mitigate bird strikes or electrocution hazard. This can be implemented when carrying out refurbishment, uprating and upgrading and building new overhead lines. Questionnaire answers by Norwegian power companies in the early 1990ies (Bevanger 1994a) revealed the following electrical installations and equipment items to be most frequently associated with bird electrocution: 1) top-mounted pin insulators, 2) steel cross-arms, and 3) pole-mounted transformers. Actual techniques to consider for use on preferred poles are e.g. insulated phase conductors, insulated cross arms, line design modifications; i.e. support or suspension insulators, pole mounted transformers, elevated perch constructions, change critical distances between phase-phase or phase-ground. Some principles to be concerned when refurbishing, uprating, upgrading and expanding power lines in order to reduce bird strikes are new design of the existing overhead line, complete undergrounding, new power lines in underground cables, new power lines in underground cables and new towers in an existing line route, new overhead lines in areas where overhead lines have already been constructed.
Decisions on the management of existing overhead transmission lines are based on the need to maximize asset utilization and return on investment. In order to accomplish this, transmis-

sion line asset owners must be proactive and aware of possible threats and opportunities to their assets. If a threat like load growth, approval for new lines, system ageing, outage constraints, lack of manpower, EMF-issues etc. is not recognized soon enough, the consequences can result in loss or underutilization of their assets. Some of the tools available to transmission line asset owners are restoration, uprating and upgrading, new lines and underground cables. This gives the transmission asset owner an opportunity to determine and implement the most economical and technical viable options to minimize conflict with wildlife and meet the increasing demand for electricity and reliability for electricity supply to customers.

4 Research approach, methods

A Identify bird hot-spots and high-risk areas for bird collisions using mobile radar technology and advanced GIS terrain modelling

Efficient GIS-modelling requires an operationalized flow of data. Efforts are needed to collect, organise and make available data on bird collisions for management, decision-makers and research. This will include:

- Establishing a national database for management of bird collision data
- Importing of all collected data into the national database
- Establishing an online system for registering new bird collisions
- Establishing a basic online map-interface for simple querying and viewing bird-collision data on a map
- Implementing a dynamic system for data publishing for use in external GIS-applications:
    - Web Map Services (WMS)
    - Web Feature Services (WFS)
    - Downloadable data such as SOSI, Shape, KM

The proposed infrastructure for management of bird-collision data will form a consistent platform for the planned GIS-activities throughout the KMB-project (A & B).

In subproject A we propose to identify areas of high bird activity (hot spots) along existing power lines and areas with high risk of bird collisions using mobile radar technology and the national database on bird collisions. A Mobile Avian Radar (DeTect inc., Florida USA) is able to record birds and bats within the power line rights-of-way and its adjacent environment; from ground level up to an altitude of more than 1000 m. Collection of ground-truth data (i.e. direct bird observations and placement of known objects) enables calibration and verification of the radar-based bird identifications. Active searches, with the help of dogs, in the power-line corridors will enable verification of the collisions recorded by the radar with the carcasses found. The radar can easily be moved to every chosen location to record bird activity and collisions. The radar will be employed to record data continuously along different power-line segments in 2-week intervals. Before and after employing the radar, the immediate surrounding of each segment will be thoroughly searched, with the help of especially trained dogs, for collision victims. Based on the resulting datasets we will be able to analyze which topographic and habitat features affect bird activity (hot spots), and especially collision rates. The bird hot spot and collision rates analyses will be done using spatial statistical methodologies (e.g. resource selection functions, combined cluster approaches, spatial statistics and autocorrelation) to find spatial differences in bird abundance and collision rates at different scales (kernel density estimates and spatial statistics (measuring geographic distribution and analyzing patterns). To identify factors contributing to an increased bird collision risk with power lines we will correlate bird flight behaviour with corresponding parameters to produce so called causal maps. Relevant parameters here may be: elevation, slope, aspect, curvature (convexity, concavity and flatness), solar radiation, climate (temperature and precipitation), wind direction, wind velocity, wind currents, land use, land cover, vegetation, habitat associations for different species, power-line characteristics. The results from these analyses will thereafter be extrapolated and visualized using advanced GIS terrain modelling to identify high-risk areas in the landscape. The maps are to be based on the national DEM with 25 meters resolution. If necessary we will have to consider development of a higher resolution DEM. The studies will be based on data available from Norge Digitalt, the Meteorological institute, NVE and the local power companies.

In order to study the possible effect power-line constructions have on bird activity, we propose an experimental design were strips of land equal to, and in the vicinity of the power line rights-of-way (i.e. comparative environment), are clear-cut. We will record bird activity in both areas employing the Mobile Avian Radar. Thereafter the bird activity recorded in areas with and without power line can be compared. When possible this can also be extended to pre- and post-construction studies where the chosen route will be monitored before and after construction (i.e. BACI-approach; Krebs 1999).

B Build a least-cost path GIS-based application for optimal routing of power lines based on ecological, technical and economic criteria

The objective of this part is to build a practical, GIS-based application that can be used to find the optimal routing for new power lines. The application will use least-cost path methodology to locate the most optimal routing based on economic, technical and ecological criteria. This least-cost application will work with relevant layers on raster format (GRID). The pixels in each raster layer will be combined mathematically in a raster calculator to create a final cost raster. This cost raster will contain a summarized cost of each corresponding pixel from all the raster layers integrated in the analysis. The least-cost path for new power lines will be calculated when the user applies his criteria (economic, technical and ecological) to the cost raster. The user platform for this application will be ArcGIS with 3D and Spatial Analyst Extensions. The necessary toolsets will be developed in Modelbuilder using ArcObjects.

C Power line rights-of-way and wildlife

The objective of this study is to evaluate how power lines at present function as wildlife biotopes and to evaluate if certain treatments of the vegetation beneath power lines will improve conditions for wildlife.

First we will assess the present value of power lines as wildlife biotopes. Spatio-temporal and habitat-related densities of wildlife species along and near power lines will be estimated using Distance methodology (Buckland et al. 2001). During winter time we will additionally register ungulate and tetraonid tracks along the lines. We will use data from the Mobile Avian Radar to gain information about the possibility of power lines being used as migration routes. Data from the radar will indicate whether certain species are more likely to move longitudinally rather than transversally and thus indicate some preference for moving along power line corridors. We will equip tetraonids with GPS radio transmitters to reveal their movement patterns and analyse existing GPS-based data for moose and roe deer. Movement patterns will be analysed using advanced spatial statistical models (i.e. resource selection functions, correlated random walks and fractal analysis) and applying GIS with regard to topography, time of year, time of day, habitat types, power line types and tree heights. The same methods will simultaneously be used in the clear cut strips (see 4A) to reveal any effects of the truss work itself.

When we have sampled a sufficient amount of data representing the current status of power line ROW as wildlife biotope, we propose an experimental design to assess if certain succession stages, alternative pruning techniques and plant compositions are more beneficial for wildlife than others. We will examine wildlife responses to several alternative treatments of the present vegetation like various cutting-heights and intervals as well as graduated transition zones to untouched vegetation along the power line. Control areas (exposed to the traditional cutting) will be juxtapositioned with treatment zones for comparison. The clear cut strips (see 4A) will be treated in the same manner enabling an assessment of the effect of the truss work itself. The same methods as described above will be applied in all areas to enable these comparisons.

D Camouflaging power lines and power-line structures

The objectives of this part are to determine how a phase conductor surfaces with different colours and/or reflection affect the ability of birds to see them and thus avoid flying into them. This is a challenging task as an in-situ testing of colour-coated power lines with paint of different colour would be expensive. However there are already in the Norwegian grid power-line section differing in colour and surface coating, and an inquiry will be made to see if adequate sections are available. Another challenge will be the amount of data available. If high-hazard bird collision sections are selected it could however, be possible to regularly patrol and search for collision victims using standard methods including use of special trained dogs along the selected power-line sections. The colour contrast for humans and birds will be recorded and the collision frequency would indicate the importance of the power line conspicuity. The visibility of novel colours to birds will be tested using behavioural choice experiments (Uppsala, Sweden) on chickens who share the vision sensitivities of grouse and on wild caught corvids. The corvids consists of mainly flying birds in open habitats, factors which are likely to influence the mechanisms used for visual discrimination. Colours that seem to have the desired properties of high visibility to birds while being inconspicuous to humans could then be tested at a larger scale in situ. The results of the behavioural experiments would also be incorporated into the "Least cost path GIS-application" (project B).

E Guidelines for technical solutions to mitigate bird strikes or electrocution hazard

The decision whether to bury a line takes into account the balance between the need to transmit electricity at minimum cost and the environmental conditions and concerns along the route. In this analysis the technological development and the importance of availability of transmission service has to be kept in mind. The main questions to be asked in connection to underground cables (UGC) are when and where earth cabling will be a technical and economic solution. The issues of costs are fundamental when it comes to comparing overhead lines (OHL) and UGC. Creating a new link by underground cables becomes more and more an issue of time constraints, biological and ecological factors, public concern regarding land use, visual impact and magnetic and electric fields. Regarding recycling costs different lifetimes of OHL and UGC should be investigated. Assessments of the advantages of underground cables like where they are not affected by ice, snow, rain, wind, salt storms, smoke or fog are also important issues. It is common practice to compare projects according to investment costs (equipment, installation and compensation to landowners) and life cycle costs (investments, losses over lifetime of the system, taxes, maintenance, repair and decommissioning). Activities regarding cables may primarily focus on smaller cable dimensions and weights with the objectives of reducing product and installation costs. Present technology for XLPE cables have reached a plateau and any gains that may still be obtained will mostly concern an optimisation of laying techniques. Although environmental considerations are key issues to assess, availability of transmission services plays a major role in comparing underground cables and overhead lines. As far as repair time is concerned, it seems that repair duration differences are still in favour of OHL. The fault rate for cables is expected to be lower than for overhead lines, thus assessment of techniques and maintenance costs regarding fault finding and repair are important question to address.

Pole-mounted transformers together with poles where over head wires are debranched into underground cables are probably of the most dangerous electrocuting devices in Norway, affecting red listed bird species like the eagle owl. In Sweden, a project was started in the 1980ies to mitigate electrocution accidents on transformers (Lindgren 1984) due to the frequent electrocution of the eagle owl *Bubo bubo*, a species with endangered status in Norway (Kålås et al. 2006). Thus, a case study focusing this species is proposed in the county of Nordland (Sleneset, Lurøy) where a population mapping project is already running. Sleneset has a population of 9-14 pairs, and the total eagle owl population in the local authority of Lurøy is estimated to 40-50 pairs. During the last twenty years members of the Rana Ornithological Society have recorded 30-40 eagle owls killed by utility structures in the area, of which about 90% were killed by electrocution, the rest by collisions (Espen Dahl pers. comm.). This makes the area suitable for mitigation experiments. Tagging of the birds (radio/satellite transmitters) and DNA analysis will be the main tools for recording and estimating mortality of birds in territories with and without mitigating measures.

PhD-project description

As a part of the project described in 4C we suggest including one PhD student. The objectives of this PhD is to assess how and why different wildlife species use power line ROW, evaluate possible positive and negative effects of power line ROW, and assess the possibilities for improving their quality as such. This study will focus on the following approaches: 1) a general assessment of wildlife densities along and in the vicinity of power lines ROW using Distance transect methodology, 2) a study of the movement patterns of tetraonid species in relation to power lines using GPS, Mobile Avian Radar and GIS, and 3) comparing findings before treatment of vegetation and after as well as in relation to control areas and strips parallel to the power line ROW. 4) A particular task to be done by the student is winter-tracking of ungulates and tetraonids using continuous GPS-logging and simultaneously recording behavioural events as feeding, resting and moving. This approach will supply the student with a generous amount of data for the thesis.

5 Project organisation and management

The project is constructed around three functional groups: regulatory (the Norwegian Water Resources and Energy Directorate), research (ecological and technological), industrial (the energy distribution companies). Together these partners have the best qualifications to identify and mitigate the main conflicts between birds and power lines. To secure the interests of all sectors, the project will appoint a project group with selected members from each contributing partner, and meet regularly to discuss progress and project management.

NINA will be the lead institution for the project, with Dr. Kjetil Bevanger as project manager. The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology (SINTEF) has the necessary competence within the specific technological issues. Our main copartner for experimental design connected to bird vision will be the University of Uppsala. In addition to the PhD-student, master students from the Norwegian University of Science and Technology (NTNU) will be invited to participate in the project. The project will be in close cooperation with Statnett. In addition, the Norwegian Electricity Industry Association (EBL) will be an important co-partner.

6 International co-operation

The project will be carried out in collaboration with European institutions and experts in fields relevant to wildlife and power lines (e.g. Dutch Society for the Study and Conservation of Mammals (VZZ)). Experts on bird vision and bird flight and animal locomotion at the University of Uppsala (UU) in Sweden, will act as scientific advisers during the project period.

7 Progress plan – milestones

Project start is scheduled for 01012009. Data collection should be completed by 3112013. Data analyses will be carried out during and after data collection to the end of 2012. The main publication will be produced in 2013.

Table 1. *Project milestones.*

Project elements	2009				2010				2011				2012				2013			
Identify high risk areas	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				
Least-cost path application													■	■	■	■	■	■		
Power-line ROWs as wildlife biotopes	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
PhD student			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Camouflaging power lines	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Guidelines for technical solutions	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■				
Technology and tools																				
Radar, deterrent and mitigating measures	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Project administration	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Reporting		■		■		■		■		■		■		■		■	■	■	■	■

8 Costs incurred by each research performing partner

Table 2. *Cost plan for each partner (1 000 NOK).*

	NINA	SINTEF	UU	NTNU	Totals
Personal and indirect costs	8 325	3 100	206	50	11 681
PhD student	1 874		0	50	1 924
Purchase of R & D services	112		0	50	162
Equipment	3 010		20	50	3 080
Operating costs	2 275		75	50	2 400
Totals	15 596	3 100	301	250	19 247

9 Financial contribution by partner

Table 3. *Cost code (economic contribution) by the project partners, and by the Norwegian Research Council (1 000 NOK).*

Year	**Statnett**	**EBL**	**BKK**	**NVE**	**DN**	**Applied for to NFR**
2009	270	150	150	150	50	4 506
2010	270	150	150	150	50	2 837
2011	270	150	150	150	50	2 758
2012	270	150	150	150	50	2 723
2013	270	150	150	150	50	2 573
Totals	1 350	750	750	750	250	15 397

The funding of the project is based on a co-operation between the energy and environmental management authorities (NVE (The Norwegian Water Resources and Energy Directorate), DN (The Directorate for Nature Management)), the industry within the energy sector (Statnett, EBL (the Norwegian Electricity Industry Association) and BKK (Bergenshalvøens Kommunale Kraftselskap)), and the Norwegian Research Council (NFR).

PART 2: Application of results

10 Relevance for knowledge-building areas

The project results will contribute to improving the knowledge base on information on bird species specific vulnerabilities to power lines, and increase the prediction power and improve the planning process in choosing the most environmentally friendly power-line routing etc.

11 Importance to Norwegian industry

a) The project will give important input to the energy industry and the energy and environmental authorities to improve planning for future power line routing and restoration of the existing grid. The management authorities as well as the energy industry need information on possible environmental consequences of power lines and what bird species and habitats that should be particularly considered. There is also a need for qualitative improvement of standardised pre-construction studies. Such information is needed not only to reduce or avoid environmental conflicts, but also to develop mitigating measures at existing power lines, and contribute to improved EIA processes.

b) A delay with respect to location and construction of power lines due to possible environmental conflicts could be an economic problem for the energy industry but also for the society as a whole. Thus, an efficient process in identifying “yes” or “no” power line routing could have a significant economic impact.

12 Relevance for call for proposals and programmes

One of the focuses of the RENERGI-programme is to create an energy system adapted to future environmental and energy challenges. The present proposal will make a significant contribution to this.

13 Environmental impact

The project results will give significant, increased knowledge about how power lines affect birds adversely in Norway. It will particularly contribute to a better planning process, and give a tool for the pre-construction period to identify areas with high conflict potential.

14 Information and dissemination of results

This is a project addressing issues with a significant level of conflict, not only in Norway, but world-wide. Thus the information strategy will be based on 1) dialogue with the energy industry and information to the public locally, regionally and nationally, 2) annual progress reports and a final report from each research component (when the components represent a thematic, separate objective making it pertinent to do so), as well as an overall final report (in English with Norwegian summary), 3) scientific papers presenting the main results from the separate project components. The results will also be popularized in written media, including newspapers and magazines. Progress reports will be completed at the end of each fiscal year to be sent to institutions financing the project, and made available to the general public through the NINA web site. A larger, final report will be distributed (in the same fashion) at the end of the project period. Results from the study will be presented at international conferences and submitted to international peer-review journals as these become available during the course of the project. We plan to publish results from each study, and also integrate results across disciplines where practicable.

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Appendix 2. *Invitation for the OPTIPOL kick-off meeting April 23 2009*.

NINA
Norsk institutt for naturforskning

Møteinvitasjon

Oppstartmøte "*Optimal design and routing of power lines; ecological, technical and economic perspectives*" (OPTIPOL)

Som tidligere kommunisert holder vi et oppstartmøte for dette prosjektet i NINAs lokaler i Trondheim 23.4. kl 1000-1400. Intensjonen med møtet er å presentere de foreløpige planene vi har for gjennomføring av de enkelte delprosjektene for representanter fra de institusjoner som sammen med Norges Forskningsråd bidrar til å finansiere prosjektet (Statnett, EBL, NVE, DN).

1000-1020	Velkommen. Prosjektets overordnede målsettinger, relasjoner til CEDREN m.m. (Kjetil Bevanger)
1020-1050	En "least-cost path" GIS-basert applikasjon for optimalt trasevalg av kraftledninger; radar som verktøy for datainnsamling (Roel May)
1050-1110	Nasjonal database for registrering av fugl drept pga. kollisjon/elektrokusjon (Roald Vang)
1110-1140	Effekter av kraftledninger/ryddebelter på vilt; negative/positive perspektiver; innhold for en PhD- og postdocstilling (Sigbjørn Stokke)
1140-1200	Spørsmål og diskusjon
1200-1230	Lunsj
1230-1250	Utfordringer ved bruk av fargekamuflering og merkemetoder på kraftledninger. Hvilke arter bør fokuseres i forhold til kollisjonsproblematikk; metodikk prosjektdesign (Kjetil Bevanger)
1250-1310	Hubro – hva trenger vi av ny kunnskap for å identifisere/verifisere kritiske strukturer i ledningsnettet; tiltakenes prioritetsrekkefølge (Jan Ove Gjershaug)
1310-1330	Teknisk design og løsninger som reduserer faren for fuglekollisjoner eller elektrokusjon; muligheter og tekniske begrensninger (Steinar Refsnæs)
1330-1400	Diskusjon

Appendix 3. *Program for a one day seminar on eagle owl, wind power and power lines*.

Direktoratet for
naturforvaltning

NVE

Temadag om vindkraft, kraftledninger og hubro

Tid: Tirsdag 24. februar 2009

Sted: Trondheim, Rica Nidelven Hotel

Program:

1130-1200	Registrering
1200-1230	Status vindkraft i Norge Lars Håkon Bjugan, NVE
1230-1300	Status for Handlingsplan for hubro i Norge v/ Lars Løfaldli, DN
1300-1400	Lunsj
1400-1430	Vindkraft, kraftledninger og fugl – en kunnskapsstatus v/ Kjetil Bevanger, NINA
1430-1500	Biologi og bestandsstatus hos hubro v/Karl-Otto Jacobsen, NINA
1500-1515	Kaffepause
1500-1530	Hubroundersøkelser i Rogaland Bjarne Oddane, Naturforvalteren AS
1530-1550	Hva må gjøres for å sikre hubroen i Norge Ingar Jostein Øien, NOF
1550-1610	"Lurøy kommunes erfaringer med hubro på Sleneset" v/ Carl Einar Isachsen jr., Ordfører i Lurøy kommune
1610-1630	Kaffepause
1630-	Kommentarer og spørsmål
1900	Felles middag

Invitasjonsliste:

NVE, DN, OED, MD, NINA, NOF, Naturforvalteren AS, Statkraft Agder Energi Vind DA, Statnett SF, Fred.Olsen Renewables AS, Nord-Norsk Vindkraft AS, Norsk Vind Energi AS, Sarepta Energi AS, Zephyr AS, Lyse Produksjon AS, Statskog SF, ASK Rådgivning, AMBIO Miljørådgivning AS, Fylkesmannen i Nordland, Nordland fylkeskommune, Fylkesmannen i Rogaland, Rogaland fylkeskommune, Fylkesmannen i Sør-Trøndelag, Sør-Trøndelag fylkeskommune, Fylkesmannen i Nord-Trøndelag, Nord-Trøndelag fylkeskommune og Lurøy kommune.

Appendix 4. *Minutes from a meeting 12.6.2009 on ”How to better utilize existing ungulate GPS-data”.*

Møtereferat. OPTIPOL, lineære strukturer og postdocstilling Hvordan kan vi bedre utnytte eksisterende GPS-data for hjortevilt?

Møte avholdt 12. juni 2009 på NINA, kl 12.00 til 16.00
Møtedeltakere: Roel May, Kjetil Bevanger, Sigbjørn Stokke, Christer Rolandsen, Olav Strand og John Linnell (alle NINA), Erling Meisingset (Bioforsk, Tingvol) og Jonathan Colman (UIO)
Forfall: Vebjørn Veiberg og Knut Langeland (begge NINA)

Roel May ønsket velkommen og la fram agenda for møtet. Deretter orienterte Kjetil Bevanger om CEDREN og OPTIPOL. Dette var svært nyttig etter som mange ikke helt visste hva disse akronymene innebærer. Alle vil få adgang til CEDREN sin eRoom for å holde seg orientert om hva som skjer. Etter dette presenterte møtedeltakerne sine prosjekter hvor GPS-posisjoner for ulike hjorteviltarter er innsamlet.

Christer Rolandsen: har 171 elger med GPS i Nord Trøndelag. De første merket i 2006. I tillegg har han tilgang til fallviltregisteret med data fra 1990. Fylkesmannen er prosjektleder. Sluttrapport skal leveres i 2010. Samarbeider med SLU. Ser primært på analyser av bevegelser, delvis knyttet til veier.

Erling Meisingset: ser mest på arealbruk og trekkmønster for hjort. Har til sammen merket 350 hjorter med GPS, hvorav bla. 53 i Hordaland vest for Hardangervidda, 120 fra Molde og nordover samt 20 i Hallingdal. Har et konkret oppdrag for Statens vegvesen/vegdirektoratet ift hjort og vei. Her studeres både avoidance, kryssing av veier (barrierer) og risikosoner for påkjørsler. Det benyttes også påkjørselsdata til dette arbeidet. Rapport skal leveres til vegvesenet i desember. I tillegg er det planlagt en artikkel (kan hende to) på dette temaet.

Jonathan Colman: har merket noen villrein i Setesdal hvor det går en 420 Kw kraftledning – relevant for lineære strukturer. Har 22 tamrein merket på Røros hvor det kommer en 420 Kw kraftledning og derved får man en god mulighet til å studere før- og etterresponser, noe som det sjelden blir mulighet til. I tillegg er det merket tamrein på Fosen og på Vannøy hvor det kommer vindmøller slik at man også der kan studere før- og etterresponser. Det er stort sett gjort deskriptive analyser og fint lite i forhold til lineære strukturer.

Olav Strand: har 70 virksomme GPS-sendere på villrein i Langfjella. Ser på villrein og relasjoner i forhold til inngrep. I tillegg har det blitt igangsatt et sammenlignbart prosjekt på Dovre. Har brukt resource selction functions og correlated random walks tilnærminger. Olav Strand og Kjetil Bevanger hadde på forhånd diskutert en mulighet for å se på villrein i forhold til barrierer grunnet vassdragsreguleringer/vannkraftutbygging i områdene ved Blåsjø, Knutshø og Aursunden. Olav Strand mener at man også bør se på hvordan åpne elver i vintrhalvåret (grunnet regulering) påvirker villrein.

John Linnell: har cirka 20 GPS-sendere på rådyr. I tillegg har han tilgang til gaupe data hvis det blir aktuelt. I et nytt INTERREG-prosjekt i Nord-Trøndelag skal det radiomerkes tamrein.

Roel May og Sigbjørn Stokke presenterte deretter noen forslag til aktuelle problemstillinger som innledning til diskusjon over temaet. Sentralt i diskusjonen var tema som hvilke kvalifikasjoner en postdoc bør ha, forvaltningens behov, kunnskapsbristen når det gjelder habitatforståelse, effekten av populasjonstetthet på arealbruken, viktigheten av å forstå/tolke dyras bevegelse og avgrensing av problemstillinger. Deltakerne fikk tildelt kopi av svarbrevet fra Statens Vegvesen før diskusjonen.

Det var enighet om at lite var gjort når det gjelder hjortevilt og kumulative effekter av ulike lineære strukturer og at det her er et behov for samarbeid for å få en helhetlig analytisk tilnærming til problemet. Alle frammøtte ønsket å bidra med data for å få til en slik tilnærming som vil gagne alle involverte parter. Det var enighet om at en internasjonal postdocutlysning (over 4 år med sete på NINA) var ønskelig. Det må jobbes videre med søknader for å finansiere en slik stilling.

Det ble vedtatt at Roel May og Sigbjørn Stokke skal utarbeide et forslag til problemstillinger med utgangspunkt i diskusjonen og de framlagte forslag. I det nye forslaget må det vektlegges at alle hjorteviltarter blir betraktet i et flerbruksmiljø hvor samarbeid og synergieffekter blir sentrale faktorer og at forslagene fra Statens Vegvesen må imøtekommes. I utgangspunktet bør man starte med å analysere bevegelser i forhold til lineære strukturer og eventuelt ha som mål å få fram bedre habitatbeskrivelser. Det blir viktig med konkrete samarbeidsavtaler på prosjekt- og institusjonsnivå.

Sigbjørn Stokke (referent)

Appendix 5. *Letter sent to the Norwegian Road Authorities asking for cooperation*

NINA
Norsk institutt for naturforskning

Bjørn Iuell
Statens vegvesen Vegdirektoratet
Postboks 8142 Dep, 0033 Oslo

Deres ref:
Vår ref: 351/2009-642.26
Sted:
Dato: 22.04.2009

Hjortevilt og lineære infrastrukturer
– prosjektbeskrivelse og søknad om medfinansiering av en postdoktorstilling

Vårt moderne samfunn har medført en utvikling av mange ulike lineære infrastrukturer som veier jernbane- og kraftledninger. Disse strukturene beslaglegger store arealer og medfører en betydelig habitatfragmentering som har skapt en økende bekymring i mange Europeiske land på grunn av store økologiske konsekvenser (Forman & Alexander 1998, Kareiva & Wennergren 1995). En rekke økonomiske, fysiologiske og psykiske kostnader er knyttet til lineære infrastrukturer. Kollisjoner med påfølgende menneskelige traumer, medisinske kostnader, materielle ødeleggelser, dyretraumer (kraftledninger, vei og jernbane) og båndlegging av arealer (f. eks. kraftledninger og skogbruk) er eksempler på dette (Bevanger 1994, Putman 1997). Det er derfor et stort behov for å øke vår forståelse av forskjellige dyrearters responser når de møter ulike lineære infrastrukturer. I og med vår tilgang til unike mangeårige (finskala) GPS datasett fra radiomerket elg, hjort og vill- og tam rein har vi en enestående mulighet til å studere dette på flere ulike skala- og ressursnivå.

Dette åpner en mulighet for å analysere, ved hjelp av avanserte metoder, hvordan dyrene beveger seg i forhold til lineære infrastrukturer i ulike habitat- og økosystemer. Ved å modellere bevegelsesmønstrene til dyrene i relasjon til trafikkårer (vei og jernbane) vil vi kunne identifisere kollisjonsrisikoområder hvor hjorteviltkryssinger er særlig sannsynlig. Kryssingene vil kunne relateres til tid på døgnet og derved indikere høyrisikotidspunkter. Videre vill vi kunne påvise sesongmessige variasjoner og relasjoner til ulike habitattyper. Det vil derfor være mulig (ut i fra modellen og GIS-informasjon) å si noe om hva som karakteriserer høyrisikoområder. Vi vil også adressere dyrenes bevegelse i forhold til ulike tiltak som gjerder og siktrydding. Ved å legge inn slike tiltak i modellen vil vi kunne evaluere og sannsynliggjøre dyrenes respons på tiltaket. Videre får vi en mulighet til å studere dyrenes bevegelser og resursbruk i et multibrukslandskap i og med at de lineære strukturene ofte løper parallelt over lengre strekninger. En slik studie vil gi ny informasjon om dyrene responderer forskjellig i henhold til hvor mange infrastrukturer som er til stede og hvorvidt dette påvirker de trafikale problemene.

Når det gjelder kraftledninger vil vi i tillegg til multibrukstilnærmingen studere om det er mulig å optimalisere mattilbudet for hjortevilt i kraftgatene via alternative ryddemåter. De ulike behandlingene vil bli sammenlignet med en tradisjonelt ryddet "kontrollgate" som løper parallelt med kraftgata. Dette vil på sikt kunne påvirke dyrenes bevegelsesmønster (også i en trafikkmessig sammenheng) i og med at mattilbudet vil kunne øke i kraftgatene.

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NINA forskningsstasjon, Ims
4308 Sandnes
Telefon: 51 67 24 70
Telefaks: 51 67 24 71

Side 2

Vår tilnærming har en praktisk vinkling som vil få stor regional betydning i form av økt kunnskap om: dyrs bevegelsesmønster i multibrukslandskap i rom og tid, trafikksikkerhet, fragmenteringsspørsmål og beiteressurser.

De metodiske tilnærmingene vil være basert på modellering med utgangspunkt i ulike home range tilnærminger, resursseleksjonsfunksjoner, korrelerte random walks, Levy flights, fraktal analyser og Brownian bridges (for den siste tilnærmingen har vi allerede en modell klar for bruk). Vi vil også anvende romlige GIS-baserte predikasjonsmodeller. Det blir et nært samarbeid med personer som er involvert i ulike prosjekter med radiomerkede dyr. Aktuelle studieområder og prosjekter er elgmerkingsprosjektet i Nord Trøndelag, villrein på Hardangervidda, hjort på Sunnmøre og tamrein på Røros og Lierne (http://dyreposisjoner.no/). Prosjektet blir en del av OPTIPOL-prosjektet (Optimal design and routing of power lines; ecological, technical and economic perspectives) og utføres som en del av CEDREN (Forskningssenteret for miljøvennlig energi - Centre for environmental design of renewable energy). CEDRENs hovedmål er å utvikle og formidle designløsninger for fornybar energiproduksjon som vedrører lokale, regionale, nasjonale og globale miljø- og samfunnsmessige forhold.

For å realisere denne muligheten trenger vi tilleggsressurser og da først og fremst menneskelige ressurser. En god løsning vil være at disse analysene blir gjennomført i form av en postdoc-stilling (75%) som løper over 4 år. For tiden tilsvarer dette cirka 930 000 kr pr år. Vi utreder mulighetene for å finansiere en slik stilling og ser for oss at dette best kan gjennomføres i form av et spleiselag hvor NINA, Statens vegvesen, Norges Statsbaner og Direktoratet for naturforvaltning går sammen om å finansiere en slik stilling. Vi spør derfor om dette er noe dere kunne tenke dere å gå inn for. Et samarbeid av dette formatet vil etter vårt syn bli en faglig utfordring med et stort potensial for kunnskapsheving og tekniske oppgraderinger.

Med vennlig hilsen

Inga E. Bruteig
forskningssjef

Involverte personer:

Sigbjørn Stokke (NINA)
Kjetil Bevanger (NINA)
Roel May (NINA)
Christer Rolandsen (NINA)
Olav Strand (NINA)
Erling Meisingset (Bioforsk)
Torkild Tveraa (NINA)
Jonathan Coleman (UMB)
John Linnell (NINA)
Vebjørn Veiberg (NINA)

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Appendix 6. *Letter sent to the National Rail Administration (Jernbaneverket) asking for a co-operation and economic support on research on linear structures and ungulates*.

NINA
Norsk institutt for naturforskning

Veronica Valderhaug,
seksjonsleder Jernbaneverket
Postboks 4350
2308 Hamar

Deres ref:
Vår ref:
Sted:
Dato:

Hjortevilt og lineære infrastrukturer
Kort prosjektbeskrivelse og søknad om medfinansiering av en postdoktorstilling

I februar 2009 ble åtte forskningssentre for miljøvennlig energi (FMEs) etablert. Hensikten var å etablere tidsbegrensede forskningssentra som foretar fokusert langtidsforskning av høy internasjonal kvalitet rettet mot å finne løsninger på de utfordringer vi står ovenfor innen energisektoren. CEDREN (Centre for Environmental Design of Renewable Energy) er et av disse sentrene som skal utvikle og formidle designløsninger for fornybar energiproduksjon (vindkraft, vannkraft, solenergi og bioenergi) vedrørende lokale, regionale, nasjonale og globale miljø- og samfunnsmessige forhold.

NINA (Norsk institutt for naturforskning) fikk i 2008 gjennomslag for en søknad til Norges Forskningsråd (Renergiprogrammet) som fokuserer på økologiske, tekniske og økonomiske sider ved kraftledningsbygging i Norge ("Optimal design and routing of power lines; ecological, technical and economic perspectives" (OPTIPOL). Dette prosjektet er nå innlemmet som en del av aktiviteten i CEDREN. En viktig del av dette prosjektet blir å studere hvordan hjortevilt og hønsefugler responderer på ulike kombinasjoner av lineære infrastrukturer (jernbane, vei og kraftledninger) i ulike landskapstyper. Vi vil i det følgende utdype denne problemstillingen.

Vårt moderne samfunn har medført en utvikling av mange ulike lineære infrastrukturer som veier jernbane- og kraftledninger. Disse strukturene beslaglegger store arealer og medfører en betydelig habitatfragmentering som har skapt en økende bekymring i mange Europeiske land på grunn av store økologiske konsekvenser (Forman & Alexander 1998, Kareiva & Wennergren 1995). En rekke økonomiske, fysiologiske og psykiske kostnader er knyttet til lineære infrastrukturer. Kollisjoner med påfølgende menneskelige traumer, medisinske kostnader, materielle ødeleggelser, dyretraumer (kraftlinjer, vei og jernbane) og båndlegging av arealer (f. eks. kraftlinjer og skogbruk) er eksempler på dette (Bevanger 1994, Putman 1997). Det er derfor et stort behov for å øke vår forståelse av forskjellige dyrearters responser når de møter ulike lineære infrastrukturer. I og med vår tilgang til unike mangeårige (finskala) GPS datasett fra radiomerket elg, hjort og vill- og tam rein, har vi en enestående mulighet til å studere dette på flere ulike skala- og ressursnivå.

Dette åpner en mulighet for å analysere, ved hjelp av avanserte metoder, hvordan dyrene beveger seg i forhold til lineære infrastrukturer i ulike habitat- og økosystemer. Ved å modellere bevegelsesmønstrene til dyrene i relasjon til trafikkårer (vei og jernbane) vil vi kunne identifisere kollisjonsrisikoområder hvor hjorteviltkryssinger er særlig sannsynlig (vi vil herunder benytte oss av hjorte- og fallviltregisteret). Kryssingene vil kunne relateres til tid på døgnet og derved indikere høyrisikotidspunkter. Videre vil vi kunne påvise sesongmessige variasjoner og relasjoner til ulike

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Side 2

habitattyper. Det vil derfor være mulig (ut i fra modellen og GIS-informasjon) å si noe om hva som karakteriserer høyrisikoområder. Vi vil også adressere dyrenes bevegelse i forhold til ulike tiltak som gjerder og siktrydding. Ved å legge inn slike tiltak i modellen vil vi kunne evaluere og sannsynliggjøre dyrenes respons på tiltaket. Videre får vi en mulighet til å studere dyrenes bevegelser og resursbruk i et flerbrukslandskap i og med at de lineære strukturene ofte løper parallelt over lengre strekninger. En slik studie vil gi ny informasjon om dyrene responderer forskjellig i henhold til hvor mange infrastrukturer som er til stede og hvorvidt dette påvirker de trafikale problemene.

Når det gjelder kraftledninger vil vi i tillegg til flerbrukstilnærmingen studere om det er mulig å optimalisere mattilbudet for hjortevilt i kraftgatene via alternative ryddemåter. De ulike behandlingene vil bli sammenlignet med en tradisjonelt ryddet "kontrollgate" som løper parallelt med kraftgata. Dette vil på sikt kunne påvirke dyrenes bevegelsesmønster (også i en trafikkmessig sammenheng) i og med at mattilbudet vil kunne øke i kraftgatene.

Vår tilnærming har en praktisk vinkling som vil få stor regional betydning i form av økt kunnskap om: dyrs bevegelsesmønster i flerbrukslandskap i rom og tid, trafikksikkerhet, fragmenteringsspørsmål og beiteressurser.

De metodiske tilnærmingene vil være basert på modellering med utgangspunkt i ulike hjemmeområdetilnærminger (home range), first passage time analyser, resursseleksjonsfunksjoner, korrelerte random walks, fraktalanalyser, area restricted search patterns og Brownian bridges (for den siste tilnærmingen har vi allerede modeller som er klare for bruk). Vi vil også anvende romlige GIS-baserte prediksjonsmodeller. Det blir et nært samarbeid med personer som er involvert i ulike prosjekter med radiomerkede dyr. Aktuelle studieområder og prosjekter er elgmerkingsprosjektet i Nord Trøndelag, villrein på Hardangervidda og Dovre, hjort i Møre og Romsdal, Sør-Trøndelag (og evt. Hordaland) og tamrein i Nordland, på Røros og i Lierne.

For å realisere denne muligheten trenger vi tilleggsressurser og da først og fremst menneskelige ressurser. En god løsning vil være at disse analysene blir gjennomført i form av en postdoc-stilling som løper over 4 år. For tiden tilsvarer dette ca 930000 kr pr år. Vi utreder mulighetene for å finansiere en slik stilling og ser for oss at dette best kan gjennomføres i form av et spleiselag hvor NINA, Statens vegvesen, Jernbaneverket og Direktoratet for naturforvaltning går sammen om å finansiere en slik stilling. Vi spør derfor om dette er noe dere kunne tenke dere å gå inn for. Et samarbeid av dette formatet vil etter vårt syn bli en faglig utfordring med et stort potensial for kunnskapsheving og tekniske oppgraderinger.

Med vennlig hilsen

Involverte personer:

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Appendix 7. *The OPTIPOL PhD-announcement*.

BIO xx/09 (PhD)
Power-line rights-of-way as wildlife biotopes

At present there are more than 200 000 km of power-lines in Norway and all vegetation below them are deforested to maintain security. Most real estate holders regard these areas as rather useless and unproductive. The objectives of this PhD is to assess how and why different wild-life species use deforested areas below power lines, evaluate possible positive and negative effects of power-line ROW, and assess the possibilities for improving their quality as such.

The PhD-position is part of the project "*Optimal design and routing of power lines; ecological, technical and economic perspectives*" (OPTIPOL) funded by the Norwegian Research Council within the RENERGI-programme. The project has now become part of the Centre for Environmental Design of Renewable Energy (CEDREN). The objective of the project is to develop predicting tools for optimal routing of power lines from an environmental perspective and assess technical and economic solutions to minimize conflicts with wildlife and habitat conservation. The project aims to take the focal issues related to wildlife and energy distribution a step forward by addressing new technical solutions for practical and sound economic mitigating measures, newly developed avian radar technology and advanced GIS-analyses techniques. The complex nature of the problems involved necessitates a team of scientists with complementary knowledge within technological and ecological issues working closely together. The research questions relating to power lines and wildlife illustrates the need for basic knowledge on a variety of biological and ecological factors, in particular those related to species-specific life history and behavioural ecology, morphology, biomechanics and physiology.

Bird death due to electrocution or collision with power lines has long been a focal issue for energy as well as environmental managers. Another focus of attention is the power-line rights-of-way (ROW), which constitute an economic problem tying up huge land areas e.g. for the forestry sector. At the same time they constitute a specific habitat type which could benefit some species while others may suffer. The objectives of this PhD is to assess how and why different wildlife species use power-line ROWs, evaluate possible positive and negative effects of power-line ROWs, and assess the possibilities for improving their quali**ty as wildlife biotopes as such.** This study will focus on the following approaches: 1) a general assessment of wildlife densities along and in the vicinity of power-line ROW using Distance Transect Methodology, 2) a study of the movement patterns of tetraonid species in relation to power lines using GPS, Mobile Avian Radar and GIS, and 3) comparing findings before treatment of vegetation and after as well as in relation to control areas and transects parallel to the power-line ROW. 4) A particular task to be done by the student is winter-tracking of ungulates and tetraonids using continuous GPS-logging and simultaneously recording behavioural events as feeding, resting and moving. Also, the candidate will be responsible for the employment of the Mobile Avian Radar. This approach will supply the student with a generous amount of data for the thesis.

Suitable background: We seek a solution-oriented, creative person who can work both independently and in close cooperation with the project team, and who is motivated to combine innovative applied research related to power-line issues, with basic ecological research. Analytical and written skills, motivation, and the ability to work independently and in practical problem solving will be taken into consideration; and experience with ecological fieldwork, GIS and/or experience in application and development of statistical models would be an advantage.

For more information, please contact Senior Research Scientist Dr. Kjetil Bevanger (kjetil.bevanger@nina.no, +47 73 80 14 44; fax: +47 7380 1401) or Senior Research Scientist Dr. Sigbjørn Stokke (sigbjorn.stokke@nina.no, +47 73 80 15 50). Contact persons at NTNU are Professor Eivin Røskaft (roskaft@bio.ntnu.no) or Associate Professor Dr. Bård Stokke (bard.stokke@bio.ntnu.no).

Applicants should have a minimum qualification of an internationally recognized Master's degree or equivalent. In order to be accepted as a PhD student at NTNU, the grades of the MSc degree has to be sufficiently high (B or better), or the applicant has to document similar level through later scientific work. The applicants should also provide a short (max 500 words) description of the reasons why he or she is particularly suited for the position. Applications may be submitted electronically and/or on paper. They must contain information on education, university degrees, and relevant experience. NINA is working actively to recruit more women in research positions, and women are encouraged to apply. The highest rated candidates will be called for interview.

The candidate will be working at the Norwegian Institute for Nature Research (NINA), Department of Terrestrial Ecology, at NINA headquarters in Trondheim. The 100%-position will be held for 4 years, of which 25% consists of other tasks. NINA has c.160 employees and is the largest research institute within applied terrestrial and aquatic ecology in Norway, with about 90 research ecologists, PhD students, post-docs and research assistants and administrative staff, of which about 100 are located in Trondheim. More information on NINA and NTNU can be found at www.nina.no and www.bio.ntnu.no.

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