NINA Report 619

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

Progress Report 2010

Kjetil Bevanger, Gundula Bartzke, Henrik Brøseth, Espen Lie Dahl, Jan Ove Gjershaug, Frank Hanssen, Karl-Otto Jacobsen, Pål Kvaløy, Roel May, Roger Meås, Torgeir Nygård, Steinar Refsnæs, Sigbjørn Stokke, Roald Vang

CEDREN Centre for Environmental Design of Renewable Energy

Forskningsrådet Norges vassdrags- og energidirektorat NVE Statnett EnergyNorway

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Norwegian Institute for Nature Research

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CLIENTS' CONTACT PERSON(S)
Frank Nilsen (NFR)
Einar Wilhelmsen (EnergiNorge)
Johan O.X.B. Bjerke (Statnett)
Nils Henrik Johnson (NVE)
Snorre Stener (DN)

COVER PICTURE
Fieldwork in Bangdalen. Photo: Henrik Brøseth

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CONTACT DETAILS

NINA head office
NO-7485 Trondheim
Norway
Phone: +47 73 80 14 00
Fax: +47 73 80 14 01

NINA Oslo
Gaustadalléen 21
NO-0349 Oslo
Norway
Phone: +47 73 80 14 00
Fax: +47 22 60 04 24

NINA Tromsø
Polarmiljøsenteret
NO-9296 Tromsø
Norway
Phone: +47 77 75 04 00
Fax: +47 77 75 04 01

NINA Lillehammer
Fakkelgården
NO-2624 Lillehammer
Norway
Phone: +47 73 80 14 00
Fax: +47 61 22 22 15

www.nina.no

Abstract

Bevanger, K., Bartzke, G., Brøseth, H., Gjershaug, J.O., Hanssen, F., Jacobsen, K.-O., Kvaløy, P., May, R., Meås, R., Nygård, T., Refsnæs, S., Stokke, S. & Vang, R. 2010. Optimal design and routing of power lines; ecological, technical and economic perspectives (OPTIPOL). Progress Report 2010. – NINA Report 619. 51 pp.

The OPTIPOL project - "*Optimal design and routing of power lines; ecological, technical and economic perspectives*" – has been active for two years, although the main operational phase was delayed until autumn 2009. The overall OPTIPOL objective is to develop knowledge and tools to improve the decision on environmental friendly power-line routing. To achieve this goal the work is subdivided into 9 focal areas:

- Develop a "*least-cost path*" GIS-based application for an environmental friendly routing of power lines based on ecological, financial and technological criteria.
- Assess habitat use of power-line Rights-of-Way (ROW) by different wildlife species, consider actions of improving power-line ROW as wildlife habitats, and evaluate possible positive and negative effects on wildlife of power-line ROWs. More specific we will examine how power-line ROW may offer suitable feeding grounds for moose and see if the species habitat selection is influenced by power line ROW.
- Assess population impact of bird mortality 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).
- Identify ecological high-risk factors for bird collisions, i.e. site-specific factors connected to topographic characteristics, including vegetation structure, season, weather and light conditions.
- Establish a national infrastructure for management of dead bird data (including birds recorded as collision and electrocution victims) by developing an online web application enabling the general public to contribute with data on recorded dead birds via Internet.
- Review available literature to assess 1) the possibilities for increased collision hazard to birds by making power-line structures less visible for humans given the present knowledge on bird vision, and 2) technical properties and constraints of camouflaging techniques on conductors and earth wires.
- Review available literature on technical modifying solutions and assess their effectiveness to mitigate bird collisions and electrocution.
- Develop guidelines for technical solutions to mitigate power-line induced mortality to birds.
- Assess eagle owl mortality and population impact caused by power-line collision and electrocution, and identify high-hazard collision and electrocution structures.

The work with a "*Least Cost Path*" (LCP) tool for optimal routing of power lines has started and a pilot version of a "*LCP-GIS-toolbox*" is ready and will be further developed in 2011. A main challenge will be to identify thematic areas and parameters and prepare these for a geodatabase. An expert panel will be appointed which will – under three workshops – identify agreed value criteria, and how these should be weighted. The work for making a LCP-GIS toolbox will start in June 2011.

A 6km section of a 300kV transmission line, owned by Statnett, in Bangdalen (Namsos local authority) is selected for field work to collect data on the wildlife use of the clear-felled corridor. The data collection on habitat use is assisted by wildlife cameras. Although a particular focus is directed towards the moose, data on other species like red fox and mountain hare is obtained as well.

Data collection (line transects and DNA sampling) on capercaillie and black grouse started in March 2010 in Bangdalen. However, the area showed up to be unsuitable both due to the rugged topography and low densities of the target species. Thus, a more optimal area, in connec-

tion to a 300kV transmission line owned by Statnett, was identified and selected for further fieldwork in Ogndalen, east of the city of Steinkjer. DNA-sampling and data collection on bird densities by following line transects will commence in March 2011. At the same time regular patrolling along the power line to find collision victims will start.

To improve the basis for achieving optimal power-line routing that will reduce the bird collision it is important to identify areas involving a high collision hazard and the characteristics of them. Thus, it is imperative to understand what topographic and other environmental factors, e.g. vegetation structure, contributing to increased collision hazard. To achieve this existing dataset from other projects will be reanalyzed, and new data will be collected in connection to the field work in Ogndalen. The wachtel dog that was bought by the project in the autumn 2009 has now been trained for locating dead birds for more than a year and will assist during the efforts to find collided birds. This subproject will be prioritized in 2011.

The aim of identifying species- and site-specific factors affecting the collision hazard is also the rationale behind the subproject aiming at activating the general public to assist in the data collection by reporting on dead birds found via Internet. Although a functional prototype of the database was finished in 2009, NINA addressed the possibilities to co-operate with The Norwegian Biodiversity Information Centre (NBIC) in early 2010. The NBIC already has a species observation portal - *artsobservasjoner.no*. – which has become a very popular web site and is accessed by several people contributing with hundreds of observations daily. The NBIC has to undertake some adjustments of the activity list for death causes have to be expanded. This operation was difficult to speed up, however, the NBIC have assured that the system will be functional at the end of 2010.

The work on assessing the efficiency of equipment to increase the visibility of overhead wires to birds and solutions to reduce bird electrocution hazard is commenced. So is the work on colour camouflaging of power lines, and this part of the project will be finalised in 2011. One of the deliverable will be a mini-guide that can be distributed to the grid owners advising on immediate mitigating actions which may be implemented.

The work on guidelines for and evaluation of technical solutions to reduce bird collision hazard and electrocution in the old grid system as well as in connection to new constructions has been in progress throughout the year. Corrosive tests on phase conductors covered with different types of isolating materials has been initiated to follow the degradation process up to 12 years in different marine environments.

The eagle owl is known to be killed in connection to different power line structures; electrocution being the main threat although it also sometimes flies into the over head wires. Thus the species was a natural choice as a model species to study the electrocution and collision hazard, and to develop solutions and mitigating measures. The studies of the extent and population consequences of eagle owl mortality due to power lines have continued in 2010. One of the data collecting tools is satellite telemetry, and the birds are caught on their nest and equipped with a satellite transmitter back pack. Unfortunately the species had a very low breeding success this summer in the study area, possibly due to low rodent densities and only one individual was tagged. This individual has transmitted important data throughout the autumn e.g. regarding the use of power-line pylons as hunting posts.

Kjetil Bevanger (kjetil.bevanger@nina.no)
Gundula Bartzke (gundula.bartzke@nina.no)
Henrik Brøseth (henrik.broseth@nina.no)
Espen Lie Dahl (espenlie.dahl@nina.no)
Jan O. Gjershaug (jan.o.gjershaug@nina.no)
Frank Hanssen (frank.hanssen@nina.no)
Karl-O. Jacobsen (karl.o.jacobsen@nina.no)
Pål Kvaløy (pal.kvaloy@nina.no)
Roel May (roel.may@nina.no)
Roger Meås (roger.meas@nina.no)
Torgeir Nygård (torgeir.nygard@nina.no)
Steinar Refsnæs (steinar.refsnes@sintef.no)
Sigbjørn Stokke (sigbjorn.stokke@nina.no)
Roald Vang (roald.vang@nina.no)

Sammendrag

Bevanger, K., Bartzke, G., Brøseth, H., Gjershaug, J.O., Hanssen, F., Jacobsen, K.-O., Kvaløy, P., May, R., Meås, R., Nygård, T., Refsnæs, S., Stokke, S. & Vang, R. 2010" Optimal design and routing of power lines; ecological, technical and economic perspectives" (OPTIPOL). Fremdriftsrapport 2010. – NINA Rapport 619. 51 s.

OPTIPOL - "*Optimal design and routing of power lines; ecological, technical and economic perspectives*" - har formelt lagt bak seg to års virksomhet selv om det ikke ble operasjonelt før siste halvdel av 2009 grunnet formelle uklarheter. Flere delprosjekter begynner imidlertid å finne en god arbeidsform, men noen vil av ulike årsaker først starte for fullt i 2011. Den overordnede målsettingen for prosjektet er å utvikle kunnskap og verktøy som bedrer grunnlaget for en mest mulig miljøvennlig utforming av, og et miljøtilpasset trasevalg, for kraftledninger. Arbeidet er inndelt i 9 tema:

- Utvikle en "*least-cost path*" GIS-basert applikasjon for et miljøvennlig trasévalg av kraftledninger basert på økologiske, tekniske og økonomiske kriterier
- Utvikle metoder som kan øke verdien av kraftledningsgater som leveområder for hjortevilt (i første rekke elg) og småvilt
- Undersøke de bestandsmessige effektene av dødelighet som skyldes kollisjoner med kraftledninger hos orrfugl og storfugl
- Identifisere områder med høy kollisjonsfrekvens av fugl for bedre å forstå hvilke topografiske og andre miljøfaktorer som bidrar til økt kollisjonsrisiko
- Utvikle en nasjonal database for rapportering av kollisjons- og elektrokusjonsdrepte fugler
- Vurdere effekten av merkemetoder og andre tekniske løsninger som kan bidra til å redusere dødelighet hos fugl som skyldes kollisjon og elektrokusjon
- Vurdere positive/negative effekter av fargekamuflering av kraftledninger
- Utvikle retningslinjer for/evaluere tekniske løsninger som minsker faren for fuglekollisjoner og elektrokusjon i tilknytning til eksisterende og nye ledningsnett
- Undersøke omfanget - og de bestandsmessige effektene – av dødelighet hos hubro som skyldes elektrokusjon og kollisjoner med kraftledninger

Arbeidet med et "*Least Cost Path*" (LCP) verktøy for optimal traséføring av kraftledninger er startet og en pilotversjon av en "*LCP-GIS-toolbox*" er ferdig og vil bli videreutviklet i 2011. Hovedfokus vil være rettet mot å identifisere tema og parametre, samt forberede disse for en geodatabase. Det vil bli nedsatt en ekspertgruppe som gjennom 3 arbeidsmøter skal komme frem til omforente verdikriterier, og hvordan disse skal vektlegges. Arbeidet med å bygge en LCP-GIS-toolbox vil starte for fullt i juni 2011.

Det er etablert et 6 km langt forsøksfelt i Bangdalen i Namsos kommune i tilknytning til en 300 kV kraftledning eid av Statnett, for å kartlegge hvordan viltet benytter arealene i ryddebeltet til kraftledningen. Ved hjelp av viltkamera samles data på habitatbruk i ryddebeltet, særlig i forhold til elg, men gjennom kameraene samles også informasjon om hare, rødrev m.fl.

I forhold til storfugl og orrfugl ble det igangsatt feltarbeid med linjetaksering og innsamling av DNA-prøver i Bangdalen i mars 2010. Området viste seg imidlertid å være uegnet både på grunn av topografi og svært lave bestander av skogsfugl. Det er derfor valgt et mer egnet studieområde i Ogndalen øst for Steinkjer i tilknytning til en 300 kV ledning eid av Statnett. Her er terrenget lettere og tettheten av skogsfugl høyere. Feltarbeid startes i mars 2011 (linjetaksering og innsamling av DNA-prøver). Det blir også igangsatt regelmessige takseringer langs kraftledningen for å finne kollisjonsdrepte fugler fra april 2011.

For å danne et bedre grunnlag for å finne optimale traseløsninger i forhold til å redusere omfanget av kollisjoner hos fugl er det viktig å kunne identifisere områder med høy kollisjonsfrekvens. I denne sammenheng er det avgjørende å kunne forstå hvilke topografiske og andre miljøfaktorer, f.eks. vegetasjonsstruktur, som bidrar til økt kollisjonsrisiko. Dette arbeidet er ba-

sert både på reanalyse av eksisterende data fra tidligere prosjekter, og de dataene vi vil få gjennom feltarbeidet i Ogndalen. Hunden (rasen wachtel) som ble innkjøpt i 2009 har nå vært under spesialtrening i over et år, og vil bli brukt i arbeidet med å lokalisere kollisjonsdrepte fugler.

Målet om å identifisere arts- og stedsspesifikke faktorer som påvirker fuglekollisjoner ligger også bak delprosjektet som skal engasjere publikum til å registrere funn av døde fugler via Internett. Dette er rettet mot så mange relevante brukere som mulig. En funksjonell prototype av web-applikasjonen ble ferdigstilt i fjor, men etter diskusjoner med Artsdatabanken våren 2010 ble en enig om å inngå et samarbeid for å gjøre nytte av ***artsobservasjoner.no***. Dette gir mange fordeler, bl.a. ved at det allerede er en rekke brukere av systemet, og flere hundre observasjoner registreres hver dag. Artsdatabanken må foreta noen justeringer, bl.a. ved at aktivitetslisten for dødsårsaker utvides. Dette arbeidet har tatt noe lengre tid enn opprinnelig planlagt, men Artsdatabanken har signalisert at systemet vil være operativt i slutten av 2010.

Det innledende arbeidet med å vurdere effekten av merking av faseledere og jordliner samt andre tekniske løsninger for å redusere omfanget av kollisjoner og elektrokusjon hos fugl, har fortsatt gjennom innsamling og gjennomgang av litteratur. Dette arbeidet forventes avsluttet i 2011, og vil bl.a. resultere i en ”minihåndbok” for strakstiltak som NVE kan distribuere til landets nettselskaper. Arbeidet med å evaluere effekter i forhold til fugl av fargekamuflering er også kommet i gang.

Arbeidet med å utvikle retningslinjer for/evaluere *tekniske løsninger* som minsker faren for fuglekollisjoner og elektrokusjon i tilknytning til eksisterende og nye ledningsnett har pågått hele 2010. Blant annet er det utført korrosjonstester på faseledere dekket av ulike typer isolasjonsmaterialer. Gjennom dette er det mulig å følge nedbrytningshastigheten inntil 12 år i ulike maritime miljø, dvs. der det er stor saltholdighet i lufta.

Hubro er kjent for å bli drept i tilknytning til ulike kraftledningsstrukturer. Det var derfor naturlig for OPTIPOL-prosjektet å velge arten som modellart i tilknytning til studier av elektrokusjons- og kollisjonsproblematikk, og i arbeidet med å komme frem til avbøtende tiltak. Undersøkelsene av omfanget - og de bestandsmessige effektene – av dødelighet hos hubro som skyldes elektrokusjon og kollisjoner med kraftledninger har fortsatt også i 2010. Et viktig redskap i dette arbeidet er satellittelemetri; fuglene fanges på reiret og utstyres med en ”ryggsekk” med senderutstyr med GPS-enhet. Dessverre hadde hubro svært lav hekkesuksess i studieområdet på Sleneset i 2010, trolig pga. liten bestand av smågnagere, og bare ett individ ble merket. Dette individet har imidlertid gitt verdifull informasjon om områdebruk hele høsten, bl.a. i forhold til bruk av kraftledningsstolper som sitteplass.

Kjetil Bevanger (kjetil.bevanger@nina.no)
Gundula Bartzke (gundula.bartzke@nina.no)
Henrik Brøseth (henrik.broseth@nina.no)
Espen Lie Dahl (espenlie.dahl@nina.no)
Jan Ove Gjershaug (jan.o.gjershaug@nina.no)
Frank Hanssen (frank.hanssen@nina.no)
Karl-Otto Jacobsen (karl.o.jacobsen@nina.no)
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Torgeir Nygård (torgeir.nygard@nina.no)
Steinar Refsnæs (steinar.refsnes@sintef.no)
Sigbjørn Stokke (sigbjorn.stokke@nina.no)
Roald Vang (roald.vang@nina.no)

Contents

Foreword

From 2009 inclusive, CEDREN 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), i.e. a project in close cooperation with the central energy and environmental-management authorities together with the energy sector, particularly the grid owners. Apart from the Norwegian Water Resources and Energy Directorate (NVE), the Norwegian Electricity Industry Association (EnergiNorge), and Statnett at the outset committed themselves to contribute with an annual economic support to the project (at least 20% of the total costs). The project has a 5 year lifespan (2009-2013)

Trondheim, 1 December 2010

Kjetil Bevanger
Project leader

1 Introduction

With an overhead power-line grid close to 200 000 km (http://www.ssb.no/elektrisitetaar/tab-2009-05-28-08.html), the associated rights-of-way (ROW) affect huge land areas in Norway. 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 land-owner. 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 CEDREN scientists cover most of the applied ecological challenges faced. 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 several sub-projects. The activities carried our in 2010 is reported below.

1.1 The 2010 Annual Meeting

The OPTIPOL project is dealing with activities addressed by both the grid owners as well as the environmental and energy authorities. During the year there is a more or less a continuous dialogue between the OPTIPOL research team and these bodies on different topics, however once a year we gather for more formal discussions. In 2010 we met in late November (**Appendix 1**), and the presentations given are referred to in paragraph 11.2.

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

Subproject responsibility: Frank Hanssen, Roel May

Objectives:

- Develop a "*least-cost path*" GIS-based application for an environmental friendly routing of power lines based on ecological, financial and technological criteria.

2.1 Description of work

The Least Cost Path (LCP) routing procedure has for many years been used in GIS - applications for siting linear features and corridors. LCP demands a strict scheme for calibration and weighting of the input criteria. The procedure basically consists of three steps. First a discrete cost surface has to be developed for each parameter in order to indicate the relative preference for routing in any location within the study area. Secondly an accumulated cost surface has to be generated in order to characterize the optimal connectivity from a starting location to all other locations based on the intervening relative preferences. Finally the path and corridor of least cost (least resistance) between two locations on the accumulated cost surface have to be calculated.

All relevant parameters (base map themes and derived map themes) that have to be considered for optimal routing of new power lines at a national or regional scale in OPTIPOL has to be identified from literature reviews and through dialogs with interdisciplinary expert groups (ecology, technology and economy). There will always be room for subjective expert interpretation of such parameters and their relative importance. The experts therefore have to consolidate on the definitions and the quantitative standardisation of model criteria (i.e. degrees of distance, proximity, slope, density, visibility impact, etc) and how to weight them internally according to their relative importance.

There are several theories about how to achieve consensus opinions among members of a group. One of these theories, the *Delphi Process*, was developed in the 1950s by the Rand corporation (*Bernice B. Brown. A Methodology Used for the Elicitation of Opinions of Experts. The Rand corporation, Santa Monica, California, 1968*)**.** This approach was designed to achieve consensus among a group of experts. It involves directed group interaction consisting of at least three workshops. The first workshop should be completely unstructured, asking participants to express any opinions they have on calibrating the parametric criteria in question. In the next workshop the participants should complete a questionnaire designed to rank the different criteria. In the third workshop participants should re-rank the criteria based on a statistical summary of the questionnaires from the previous workshop. "Outlier" opinions should finally be discussed and consensus sought.

The Delphi Process is applied in an optimal path analysis and corridor routing study of power lines in the USA performed by Joseph Berry et al. at the Geography Department, University of Denver). In their article "*Optimal Path Analysis and Corridor Routing: Infusing Stakeholder Perspective in Calibration and Weighting of Model Criteria, http://www.innovativegis.com/basis/present/GeoTec04/GIS04_Routing.htm*" a methodology for calibration of model criteria and weighting of parameters are outlined. The application of the Delphi process done by Berry et al. is very relevant for OPTIPOL.

Another consensus technique in participatory processes is the Adaptive Environmental Assessment and Management (AEAM) approach, which is a workshop based step-by-step dialog scoping method. Starting with a holistic view, participants in AEAM narrow the picture down to focal issues. In an OPTIPOL context this means ranked model parameters and criteria. This dialog method has also shown effective in conflict reduction processes.

The parameters that are considered relevant for optimal routing of new power lines are not directly comparable because of their character and completely different measuring units. Therefore the different measuring units need to be standardized into a common unit. Also, categorization of the parameter values into two or more classes are not realistic (binary, **Figure 1**). When for example power lines should preferably not be built within 100m proximity of buildings; does that mean it cannot be placed at 99m when that would be preferred technically (i.e. continuous, **Figure 1**)? We propose to use a fuzzy logic approach to tackle this problem. Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than accurate. Fuzzy logic variables (i.e. the different parameters) may have a degree of membership that ranges on a continuous scale between 0 (bad) and 1 (good). These degrees of membership may be managed by specific functions (e.g. linear, parabolic, sigmoid; **Figure 2**).

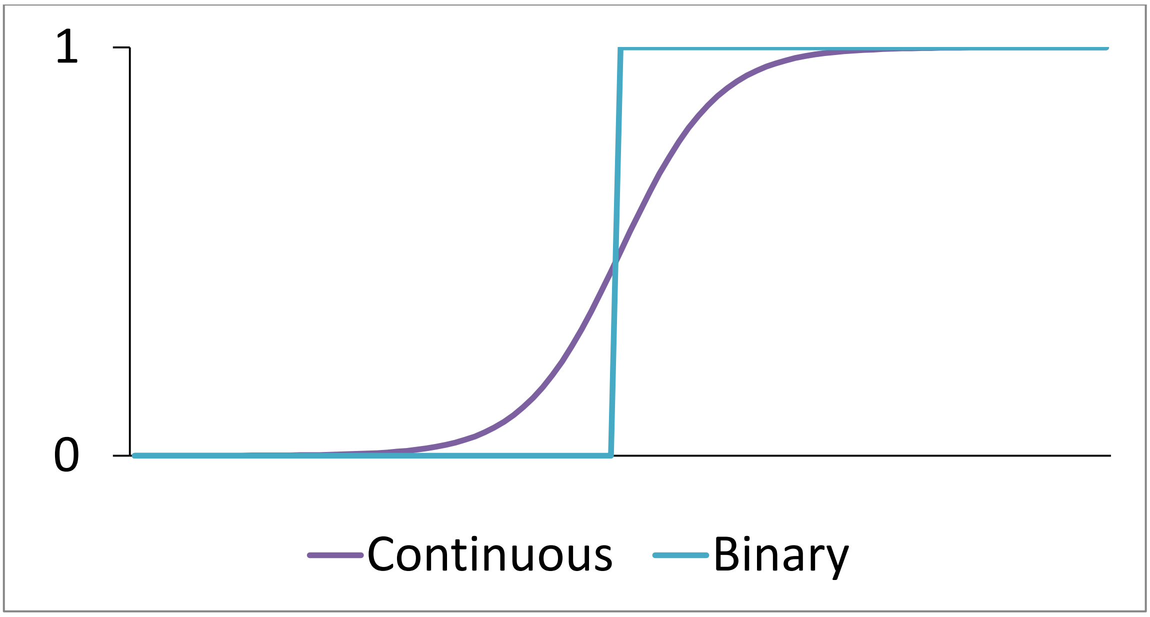


Figure 1. *Binary categorisation and continuous degree of membership.*

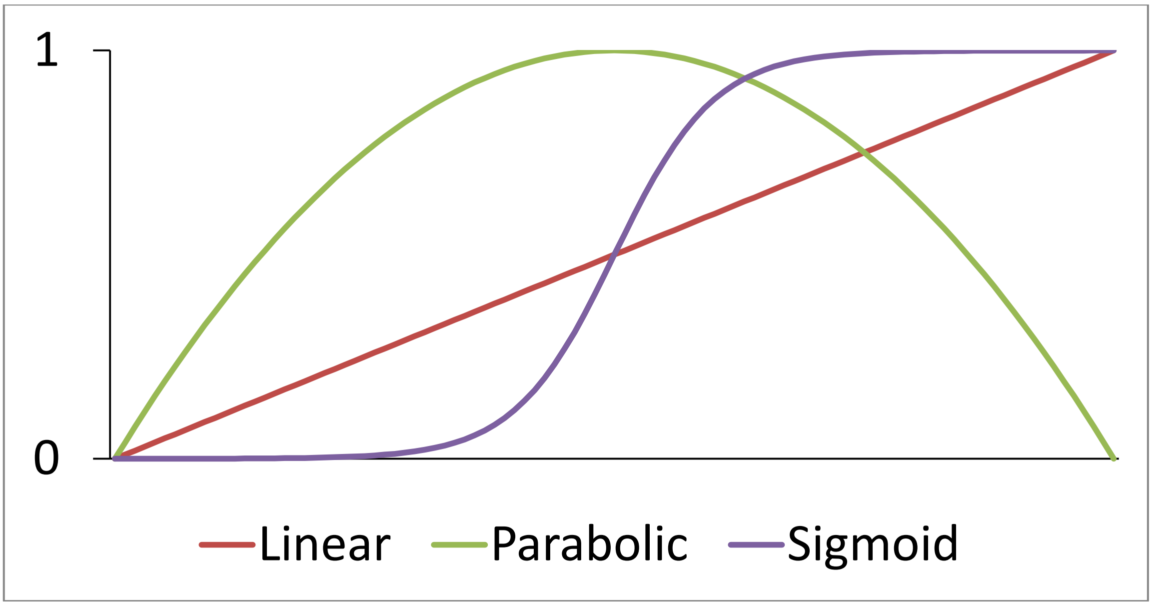


Figure 2. *Possible functions of continuous degree of membership (linear, parabolic and sigmoid).*

The most appropriate function depends on the expected relationship between the parameters' criteria values and the desired membership. In the before-mentioned example, a sigmoid function may be fitted. The exact form of the chosen function will furthermore have to be decided upon (e.g. slope, threshold, optimum) as part of a workshop with expert groups. When all relevant parameters are standardized, these can be mapped and compared. Only the importance weights of the different parameters needs to be decided upon. Consensus on this will be achieved in a series of workshops described above. The list presented below is just a draft and has to be further reviewed by the group of experts.

When the parameters are clearly defined and the criteria standardized, the necessary GIS-data will be organised into a geodatabase (both base maps and derived maps). The standardized parameters will finally be accessible for LCP-analysis through the dynamic user interface of the LCP- toolbox in ArcGIS10.

Table 1. *Draft of relevant parameters and model criteria to be further reviewed. It is highly extensive and scale dependent.*

Themes	Parameters	Criteria
Landscape	Types of landscape	• Distance from power line • Visibility
Cultural heritage	Types of cultural heritage sites	• Distance from power line • Visibility • Area conflict
Outdoor recreation and cabins	Outdoor recreation areas Cabin areas Trails (hiking, skiing and motorized vehicles)	• Distance from power line • Visibility • Noise • Area conflict
Nature	Nature types Vulnerable nature areas Animal habitats Plant habitats Seasonal function areas Animal movement paths	• Distance from power line • Visibility • Noise • Area conflict • Biodiversity richness • Disturbance • Fragmentation (barriers)
Conservation areas	Conservation areas	• Distance from power line • Visibility • Area conflict
Bird collision hot spots	Bird collision hot spots	• Distance from power line
Reindeer herding	Seasonal function areas Important movement trails Infrastructure	• Distance from power line • Visibility • Noise • Area conflict • Disturbance • Fragmentation (barriers)
Agriculture	Farmland Grassland Forested areas	• Distance from power line • Visibility • Noise • Area conflict • Disturbance • Fragmentation (barriers) • Agricultural values • Protected areas
Tourism	Popular areas and buildings	• Distance from power line • Visibility • Noise • Area conflict • Disturbance
Restricted areas	Military areas Water supply areas Power supply areas	• Distance from power line • Visibility • Area conflict
Land use plans	Agricultural, natural and recreational areas (LNF) Planned restricted areas Planned infrastructure Planned settlements	• Distance from power line • Visibility • Area conflict
Electromagnetic radiation	Electromagnetic radiation	• Distance from power line
Power lines	Technical aspects Economical aspects	• Terrain slope/elevation • Distance to existing infrastructure and settlements • Connection to the existing power supply net • Etc…

2.2 Research methods

Literature reviews will be performed in order to identify relevant LCP-parameters and to outline a methodology for standardisation of the criteria and how to weight them according to their relative importance. A process design will be set up for the expert consensus workshops. The outcome of these meetings will be converted into a quantitative scale using fuzzy logic in order to be operative in the LCP-toolbox. Finally all the relevant LCP-analytical tools have to be designed and programmatically implemented in the LCP-toolbox.

2.3 Activities 2011

The following activities are planned:

- End of November 2010:
    - Identify relevant themes and parameters
    - Prepare the parameters in a geodatabase
    - Constitution of the expert group(s)
- End of December 2010: Draft version of criteria definitions
- January 2011:
    - First expert workshop. Experts evaluate the draft list of parameters and criteria
    - Preparation of a questionnaire designed to rank the criteria
- March 2011:
    - Second expert workshop. Experts rank the criteria in the questionnaire
    - Statistical summary of the questionnaire
- June 2011:
    - Third expert workshop. Experts re-rank the criteria based on the statistical summary of the questionnaires. “Outlier” opinions are discussed and consensus finally sought
    - The geodatabase will be supplied with new themes and parameters
    - Implementation of the consensus criteria
- June 2011: Start building the LCP-toolbox

3 Power-line ROW as habitat for moose *(Alces alces)* and other wildlife

Subtask responsibility: Gundula Bartzke, Sigbjørn Stokke, Roel May, Eivin Røskaft

Objectives:
- Assess habitat use of power-line ROW by different wildlife species.
- Examine if power-line ROW can constitute suitable feeding grounds for moose.
- Investigate the influence of power lines on moose habitat selection.
- Find ways of improving power-line ROW as wildlife habitats.
- Evaluate possible positive and negative effects of power-line ROW.

3.1 Description of work

Data collection on habitat use of power-line rights-of-way by different wildlife species has been started. A study area in Bangdalen in the Namsos local authority is established, encompassing a six kilometre long section of a high-voltage power line (300kV) transversing a forested area. Through the use of wildlife cameras information is now gathered on the habitat use of this power line corridor mostly by moose (*Alces alces*), as well as mesopredators and mountain hare *(Lepus timidus)*.

To understand how and why moose may use or avoid this power line corridor, moose feeding intensity and pellet groups were recorded in random plots at different distances from the power line (**Figure 3**).

In addition, behavioural observations are gathered using wildlife cameras. On a larger scale, the responses of moose to power-line rights-of-way are investigated by analyzing extensive moose GPS location data collected in the county of Nord-Trøndelag.

To assess the possibilities for improving the browsing quality of power-line rights-of-way, a one kilometre section of the power-line right-of-way in the study area was cleared with a special clearing regime during autumn 2010. Habitat use by different wildlife species and browsing intensity will be compared between the specially cleared areas and conventionally cleared areas as well as before and after clearing.

Furthermore, potential impacts of power-line rights-of-way are assessed on a national scale. This is done by exploring how power lines are routed and which habitat types they transverse using geographical information systems.

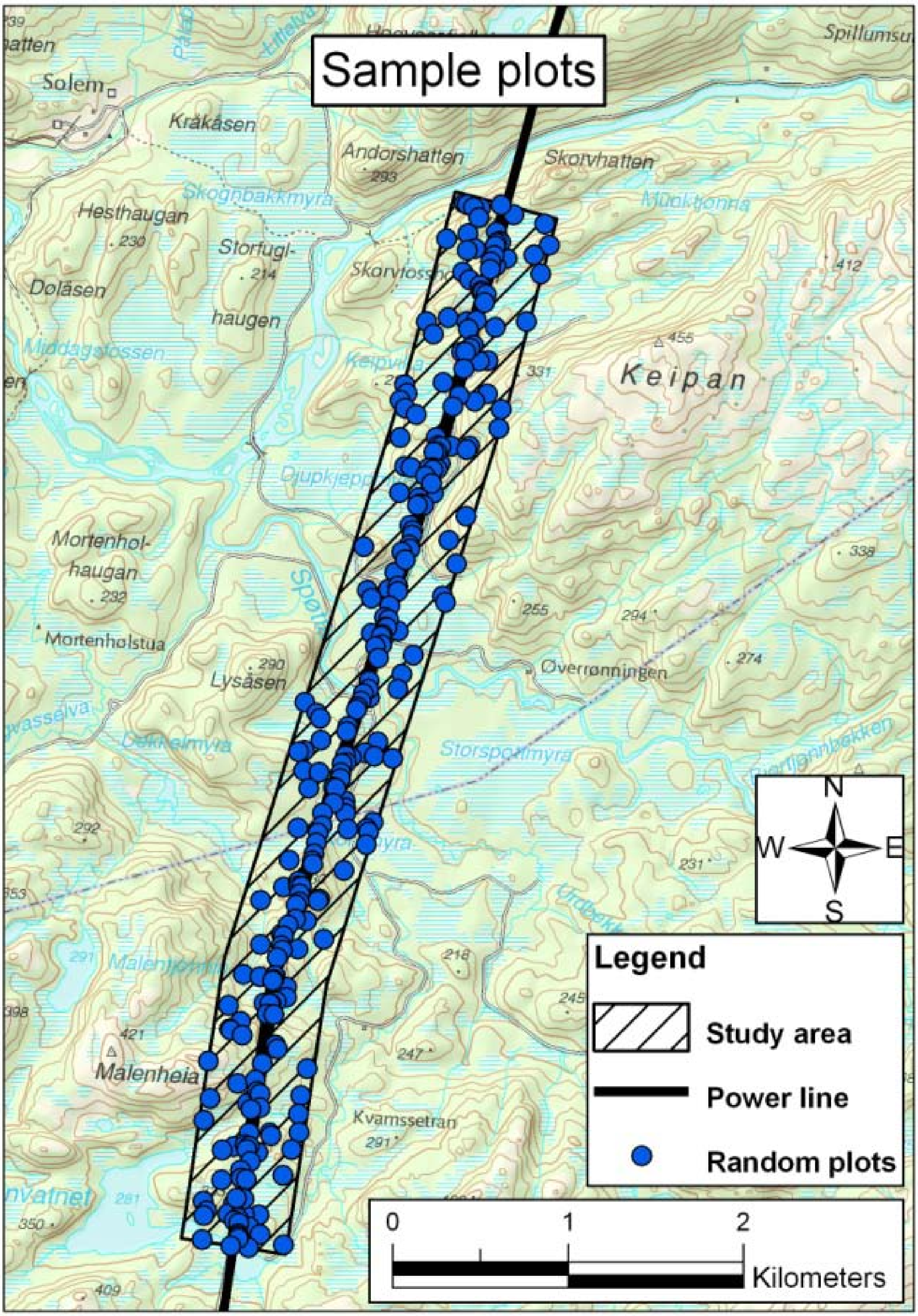


Figure 3. *Study area and sample plots surveyed for moose browsing intensity and pellet groups in Bangdalen.*

3.2 Research methods

Ten wildlife cameras are continuously recording in the study area to gather information on animal habitat use. Cameras are placed inside the different clearing regimes as well as outside the power line corridor to compare animal visitation rates between the different areas. Information on moose behaviour is gained through the near video function of the cameras. Although the animals are sometimes interacting with the cameras, behavioural activities such as feeding, movement and resting and behaviour can be observed.

Browsing intensity and habitat use by moose was further surveyed in 181 random plots up to 300 meters away from the power line. The percentage of browsed shoots of different shrub and tree species were registered (**Figure 4**) and habitat and vegetation variables were collected in each plot. At the same time pellet groups were recorded (**Figure 5**). It is planned to survey more plots extending to greater distances from the power line next year.

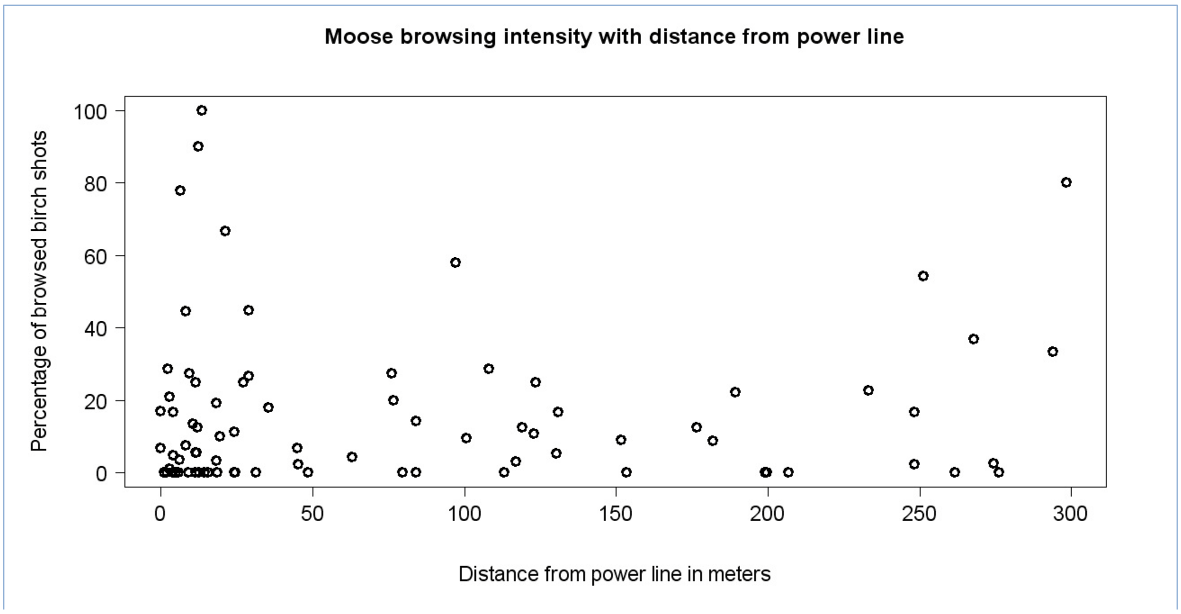


Figure 4. *Moose browsing intensity at different distances from the power line.*

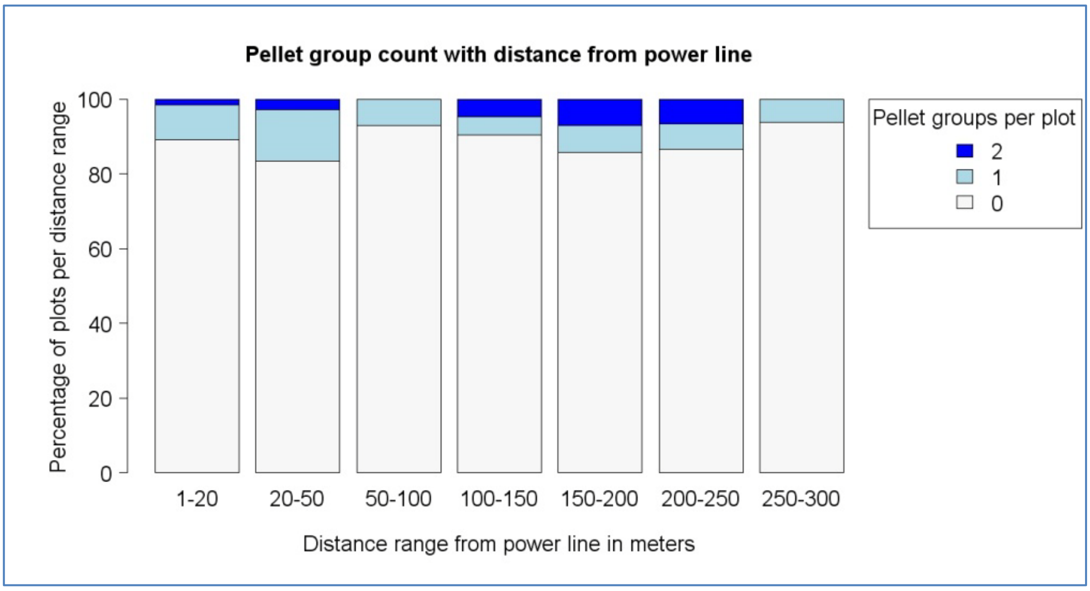


Figure 5. *Percentage of plots containing 0, 1 and 2 pellet groups in different distance ranges from the power line.*

Analysis of moose GPS data was initiated by assessing the number of moose positions (**Figure 6**) and turning angles with distance from power lines. Because moose habitat selection is influenced not only by distance to power lines, step selection functions will be used to control for the effects of habitat, other types of human infrastructure and further landscape variables.

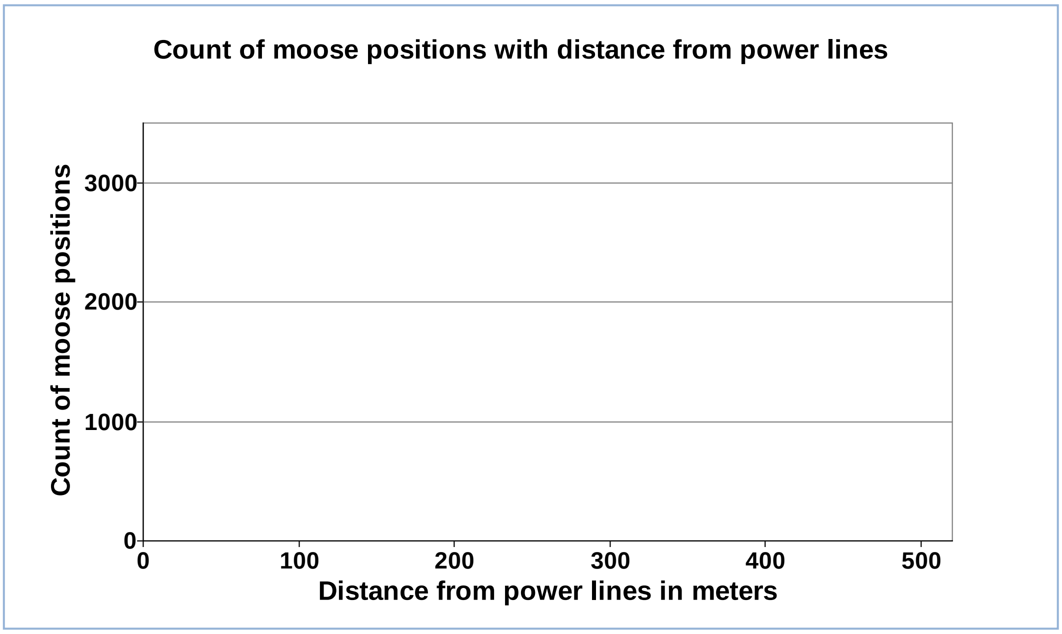


Figure 6. *Moose positions at different distances from power lines.*

A first assessment of the habitat taken up by power lines was done using the power line data from Statnett and vegetation information at NINA (**Figure 7**). Further analysis will also incorporate other landscape variables such as distance from linear structures (roads, rivers, etc.) and topographic features. Potential fragmentation impacts of power lines on ungulates will be assessed by consulting available literature.

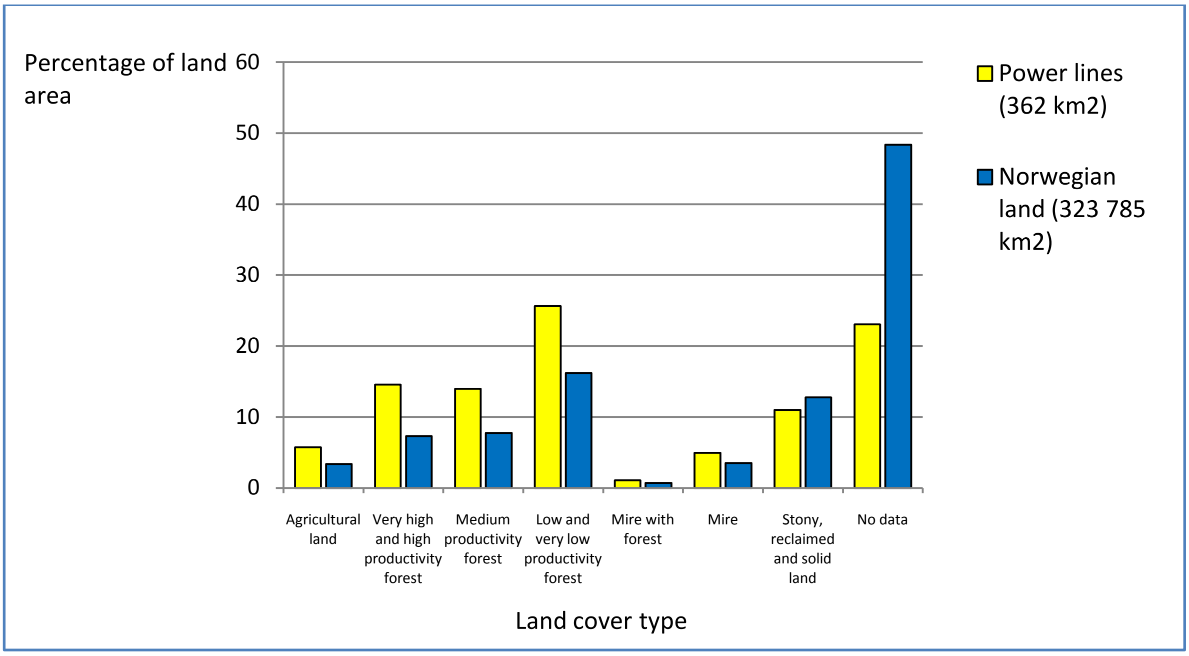


Figure 7. *Comparison of different land cover types taken up by power lines and Norwegian land as a percentage of the total land area. Width of the power-line rights-of-way ranges from 12 to 45 meters. No data refers to all land areas where no vegetation was recorded such as alpine areas, settlements and water bodies.*

4 Bird population responses to power-line induced mortality

Subtask responsibility: Henrik Brøseth, Kjetil Bevanger

Objectives:
Assess population impact of bird mortality 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).

4.1 Description of work and research methods

In an intensively studied area (30-50 km^2) we will census the population of capercaillie and black grouse over a four year period 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 a special trained dog. 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.

Very low densities of capercaillie and black grouse and very resource demanding field work in Bangdalen, made it necessary to select a new study site (a 300kV transmission line is in Ogndalen, Steinkjer) (**Figure 8, 9**). Thus the field work will be delayed with approximately one year, i.e. the field work will be initiated in March 2011.

Figure 8. *Very low densities of capercaillie and black grouse and resource demanding field work in Bangdalen, made it necessary to select a new study site in Ogndalen, Steinkjer local authority*.

Figure 9. *The new study site is located in connection to a 300 kV transmission line in Ogndalen, Steinkjer local authority.*

5 Bird collision hot-spots

Subtask responsibility: Kjetil Bevanger, Henrik Brøseth, Frank Hanssen, Pål Kvaløy, Roel May, Roger Meås.

Objectives:
Identify ecological high-risk factors for bird collisions, i.e. site-specific factors connected to topographic characteristics, including vegetation structure, season, weather and light conditions, using

- new sampled data (using special trained dog)
- existing dataset from earlier projects on birds and power lines
- the national dead-bird database
- advanced statistical/GIS-modelling

5.1 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 dog special trained to have a search image for groups of feathers and dead birds. The dog will show the handler where there is a dead bird or bird remains. A dog (a wachtel breed) was bought by the project in September 2009 and have now been trained for more that a year by the 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).

5.2 Activities

This subproject will be activated in 2011.

6 National infrastructure for management of dead-bird data

Subproject responsibility: Pål Kvaløy, Kjetil Bevanger, Henrik Brøseth

Objectives:
Establish a national infrastructure for management of dead-bird data (including birds recorded as collision and electrocution victims) by developing an online web application enabling the general public to contribute with data on recorded dead birds via Internet.

6.1 Description of work and research methods

The aim of identifying species- and site-specific factors is also the rationale behind this sub project. To identify the decisive factors triggering bird collisions with power lines and/or electrocution it is necessary to have as much data as possible on characteristics both of environmental parameters where the accidents take place, as well as design of site specific power-line structures. Patrolling power lines is a very time and recourse consuming activity, thus it will be very useful to get additional data through public observations.

In 2009 a functional prototype of the web application for registering dead birds at NINA (**Figure 10**) was developed. It incorporates topographical maps, and has the possibility of overlaying power-line maps. Some geocoding conversion functions are incorporated and it is possible to upload pictures of recorded dead birds. Some bird collision data in spreadsheet format from recent projects have been examined to determine a data structure which facilitates import.

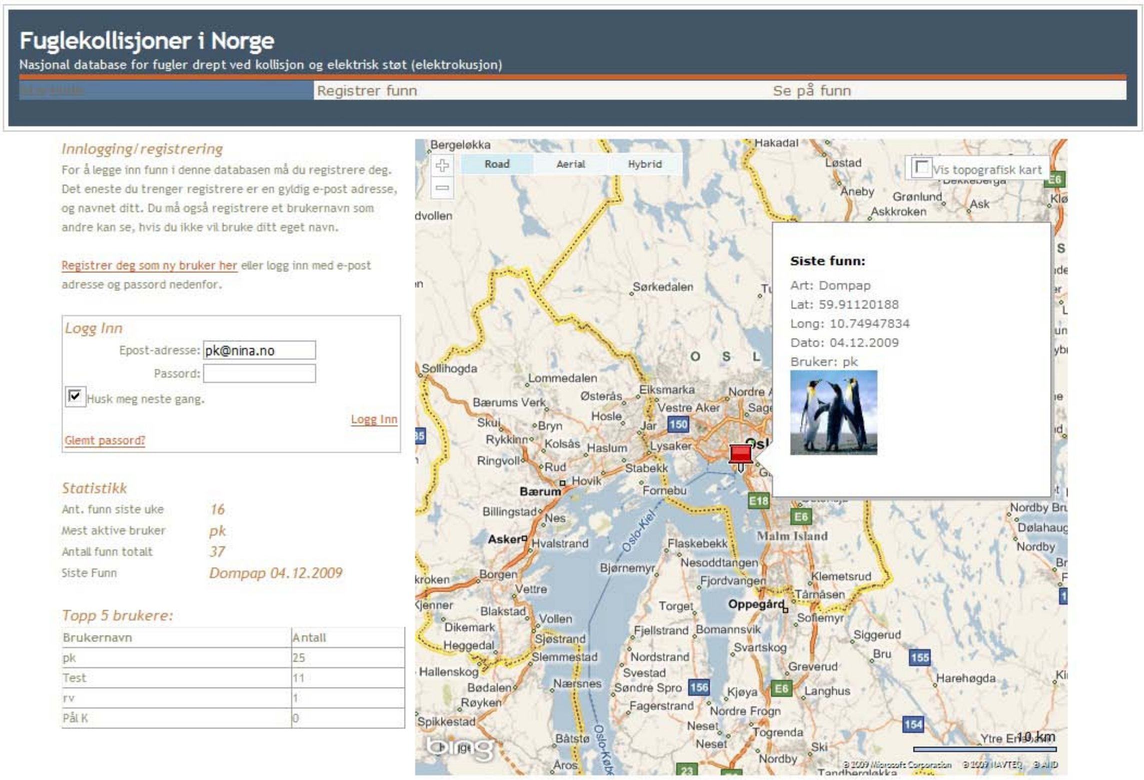


Figure 10. *Screenshot of the web application for registration of recorded dead birds.*

6.1.1 Activities and findings

Although a functional prototype of the database was finished in 2009, NINA addressed the possibilities to co-operate with The Norwegian Biodiversity Information Centre (NBIC) in early 2010. The NBIC already has a species observation portal - *artsobservasjoner.no*. – which has become a very popular web site and is accessed by several people contributing with hundreds of observations daily. The NBIC has to undertake some adjustments of the activity list for death causes have to be expanded. This operation was difficult to speed up, however, the NBIC have assured that the system will be functional at the end of 2010.

7 Ecological impact of power-line camouflaging – a review

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

7.1 Description of work and research methods

Making the power-line structures less visible for humans has recently become a topic in Norway (Johnson 2008). The rationale behind this subproject is to 1) assess the possibilities for increased collision hazard to birds if these structures are made less visible to humans and 2) is it possible to make the power line structure more visible to birds without increasing the visibility for humans. To achieve optimal detectability of a power line to birds – as well as humans - it is important to carefully consider and optimize the contrast of the wires or the towers against the background. 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.

To make an *in situ* experiment to test this would be beyond the economic capacity of the OPTIPOL project, thus these tasks are restricted to a brief literature review of
- a theoretical assessments regarding these issues based on current knowledge of bird vision
- technical properties and constraints of camouflaging techniques on conductors and earth wires

7.1.1 Making power lines more visible to birds - activities

Literature has been collected and a final review report is planned to be finalised in 2011/2012.

7.1.2 Technical properties and constraints of camouflaging techniques

The visual impact of conductors depends mainly on the phase arrangement, the number of sub conductors and the brilliance of the conductors. New untreated conductors exhibit a highly reflective surface, but usually achieve a matt finish after a few years, depending on the climate and degree of air pollution. New conductors can, however, be treated to reflect less light or to exhibit a low contrast with the background. Low reflection conductors are either obtained by clay blasting the complete conductor, by coating with camouflage colour painting or by use of special additives during the manufacturing process of wires. Proper surface treatment allows lowering the reflectivity of a new conductor to less than half of standard value of a new untreated aluminium conductor.

The ampacity of non-specular conductors is slightly increased because the emissivity of the conductor is increased from approximately 0.23, for bright shiny conductors, to approximately 0.90 because of the darker matte gray surface. An increase in current carrying capacity in the range of 5% can be achieved, for the same temperature rise, due to this increase in surface emissivity. In coastal areas with severe marine corrosivity clay blasted conductors, conductors with special additives like graphite and oil and painted conductors having a large diameter, seem to be in a steady state without accelerating corrosion after six years.

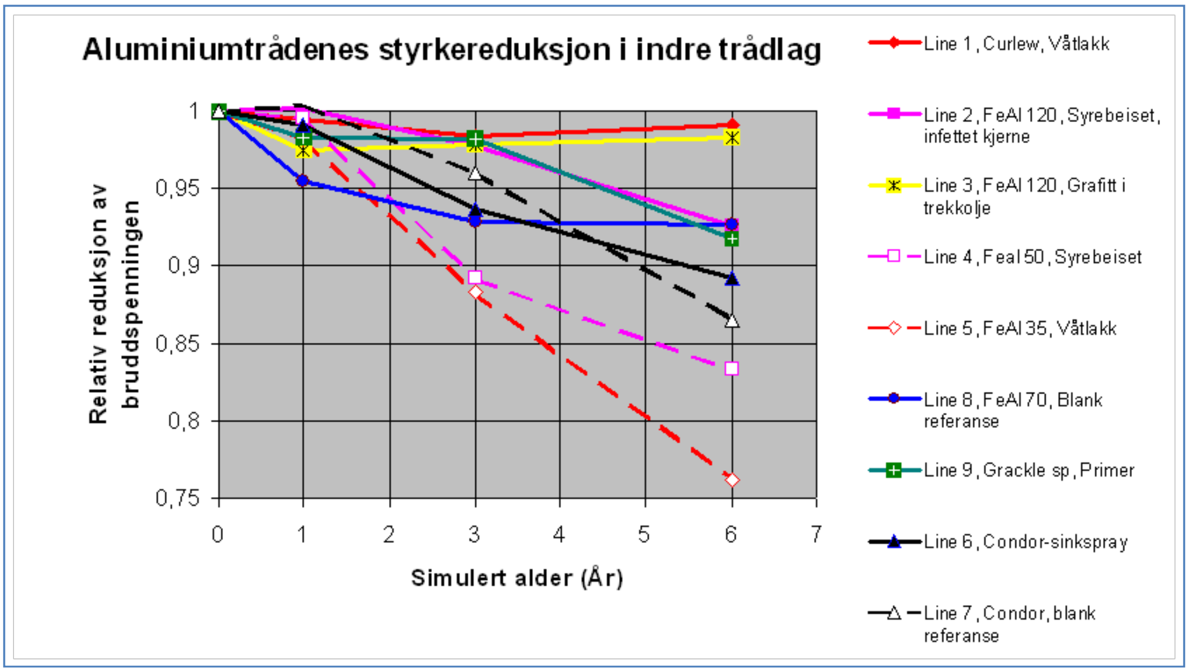


Figure 11. *The exposed conductors degradation as a function of time*.

8 Efficiency of mitigating techniques to reduce bird collisions and electrocution – a review

Subproject responsibility: Kjetil Bevanger, Espen Lie Dahl, Steinar Refsnæs

Objectives:

- Review available literature on technical modifying solutions and assess their effectiveness to mitigate bird collisions and electrocution, focusing
    - the effectiveness of reducing bird mortality by conductor marking equipment
    - the effectiveness of design methods and modifications to reduce electrocution hazard for birds
    - where and when earth cabling and other technical alternatives to mitigate bird collisions with overhead wires are justified from an ornithological point of view

8.1 Description of work and research methods

Mitigating measures to reduce power-line induced bird mortality (collisions and electrocution) has been a focal issue for many years in several countries – both due to the economic impacts of outages caused by these incidents as well as the bird species-specific impacts. Proposals to mitigate these problems have been numerous; however, it has been difficult to find general solutions of wide-ranging application and benefit. Moreover modifying utility structures has an economic cost for the net owner, and must not violate the energy supply security. The modifications must also be designed to fit the local design of the power line structures, which are highly diverse and differ from country to country.

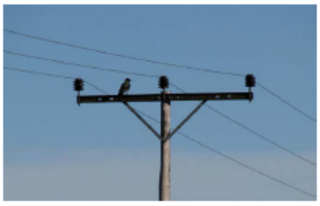
The main goal in this subtask is nevertheless to establish cost-effective line design modifications to mitigate bird strikes or electrocution hazard in Norway. This can be implemented when carrying out refurbishment, uprating and upgrading and building new overhead lines. Questionnaire answers by Norwegian power companies in the early 1990ies (Bevanger 1994) revealed several electrical installations and equipment as frequently associated with bird electrocution, particularly top-mounted pin insulators, pylons with steel cross-arms, and pole-mounted transformers.

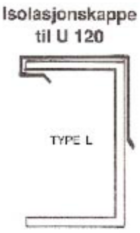
Literature has been collected and a final review report will be finalised in 2011.

8.1.1 Mini-guide for immediate actions

In late 2009 CEDREN was asked by NVE to address the mitigating issue of bird mortality and power lines, and make a mini-guide within 2010 with advices on immediate actions that could be implemented by the net owners to reduce the problem. NVE is planning to distribute this mini gude among the Norwegian net owners. A first draft was sent to NVE in early July, and we expect feed-back on the proposed content and layout within the end of the year. Example of the content is given in **Figure 12a og b**.

TILTAK FOR Å REDUSERE **ELEKTROKUSJONSRISIKO** I STRUKTURER MED PIGGISOLATOR *OG STÅLTRAVERS - Alt.1: ISOLERING AV TRAVERS*



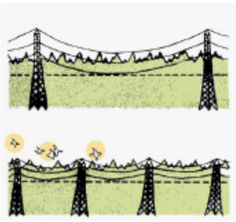


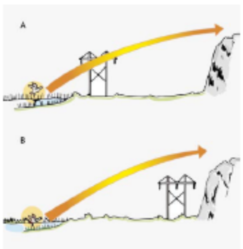
Eksempel på isolasjonskappe for travers produsert av Roza Plast A/S

Anbefalt tiltak.	Det kan være aktuelt å oppgradere eksisterende ståltravers med en isolasjonskappe.
Hvorfor bør tiltaket gjennomføres og hva oppnås?	Ståltravers med piggisolator kan være en svært utsatt konstruksjon for fugler fra kråkestørrelse og oppover. Ved å gjennomføre tiltaket unngås elektrokusjon, som kan skje ved at fuglene kommer i kontakt med en faseleder og jord, når de setter seg på eller tar av fra en kraftledningsmast med jordet mastetopp. Generelt bør piggisolatorer unngås til fordel for hengekjedeisolatorer.
På hvilket **grunnlag** baseres tilrådningen?	Informasjon innhentet hos norske energiselskaper viser at dette er en struktur det ofte observeres ulykker i tilnytning til[5]. Undersøkelser fra USA, Europa og Sør-Afrika bekrefter også at dette er farlige strukturer, og i flere land er det forbud mot bruk av piggisolator [x].
Hvor bør tiltaket gjennomføres?	Det anbefales å gjennomføre tiltaket på stopler som er spesielt utsatt. Ofte mangler systematisk kunnskap om hvilke stolper dette gjelder, men enkelte nettselskaper har lokalkunnskap som bør utnyttes. Master i områder med lite skog, og i flatt landskap med manglende naturlige utkikksposter har ofte vist seg som "problemmaster" [x].
Hvordan kan isolasjons-kappen monteres?	Isolasjonskapper kan monteres som AUS på traversen ved hjelp av isolerstang (må undersøkes nærmere)
I hvilken **grad** kan denne løsningen redusere fugledød pga. elektrokusjon?	Tilsvarende tiltak i Tyskland har bidratt til å redusere omfanget av elektrokusjonsulykker [xx].
Hvordan påvirker denne løsningen linjens **driftssikkerhet** og kan tiltaket gi **estetiske eller andre ulemper**?	I nett uten spolejordet nullpunkt vil tiltaket bedre kraftledningens driftssikkerhet i fuglerike områder. En isolasjonskappe kan gi økt korrosjon på traverser av stål eller aluminium og jordingstilkoblingen i kystnære områder.
Hva er **kostnadene**?	Merkostnaden utgjør ca xxx kr/mast [x]

Figure 12a. *Example from a proposed mini-guide on possible actions to reduce bird electrocution hazard.*

KOLLISJONSREDUSERENDE TILTAK - *Alt 1: PLANLEGGING AV KRAFTLEDNINGSTRASÉ*





A viser uheldig lokalisering sammenlignet med B.

Anbefalt tiltak.	Vegetasjon og lokale topografiske strukturer bør utnyttes ved valg av kraftledningstrase [x].
Hvorfor bør tiltaket gjennomføres og hva oppnås?	Målet er å redusere fugledød pga. kollisjon med fase- og jordline i kraftledninger og bedre kraftledningens driftssikkerhet i kollisjonsutsatte områder.
På hvilket **grunnlag** baseres tilrådningen?	Godt synlige strukturer som høye trær som får stå nær kraftledningens ryddebelte tvinger fugler til å fly høyere enn linene. Samme effekt oppnås ved at kraftledningsføringen plasseres nært opp mot bergvegger eller mindre, bratte åsrygger [x].
Hvor bør tiltaket gjennomføres?	Slike tiltak bør alltid vurderes når nye kraftledninger bygges.
Hvordan kan tiltaket gjennomføres?	Tiltaket kan gjennomføres i forbindelse med prosjektering av kraftledninger.
I hvilken **grad** kan denne løsningen redusere fugledød pga. kollisjon med liner?	Fugler flyr vanligvis over tretoppene. Når linene er lokalisert lavere enn tretoppene reduserer dette kollisjonsfaren. Topografiske strukturer som tvinger fugler til å fly over kraftledningen reduserer faren for at fugler skal kollidere med linene [x].
Hvordan påvirker denne løsningen linjens **driftssikkerhet** og kan tiltaket gi **andre ulemper** eller fordeler?	Tiltaket kan redusere antall driftsforstyrrelser i nettet pga. fasesammenslag etter kollisjon med store fugler som svaner.
Hva er **kostnadene**?	Kostnadene ved å endre traseen påvirkes bl.a. av økning/reduksjon traselengde, antall avspenningsmaster, grunnavståelse etc.

Figure 12b. *Example from a proposed mini-guide on possible actions to reduce bird collision hazard.*

9 Guidelines for technical solutions to mitigate power-line induced mortality to birds

Subproject responsibility: Steinar Refsnæs

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.

9.1 Description of work and research methods

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, transmission 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.

9.2 Activities and findings

Vertical phase arrangement, associated with high supports, tends to produce a high visual impact of the line as a whole, due to the height above ground of the conductors and of the towers, resulting in a fence effect which may also increase the risk of collision for birds.

Horizontal phase arrangement produces the opposite effects. Between these two extremes, intermediate arrangements are compromise solutions.

In a corrosion chamber we are carrying out accelerated corrosion tests on conductors covered by different insulating cover techniques in order to examine the degradation rate after one and twelve years in different marine corrosion environments, se **Figure 13a.**

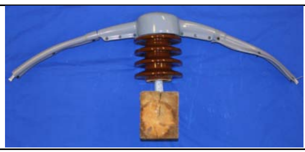
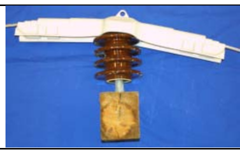
			
HUVEN UVEN AB Kabeldon	ARK 1053 Arkonia Systems	KE 116203 Kaddas Enter-prises	BIC-3312 Tyco Electronics

Figure 13a. *Conductors covered by different insulating cover techniques in the supporting point.*

An analysis of failure and disturbances in the Norwegian high voltage network showed that the failure rate in coastal areas regarding birds and animals, are much higher than in the hinterland (**Figure 13b**).

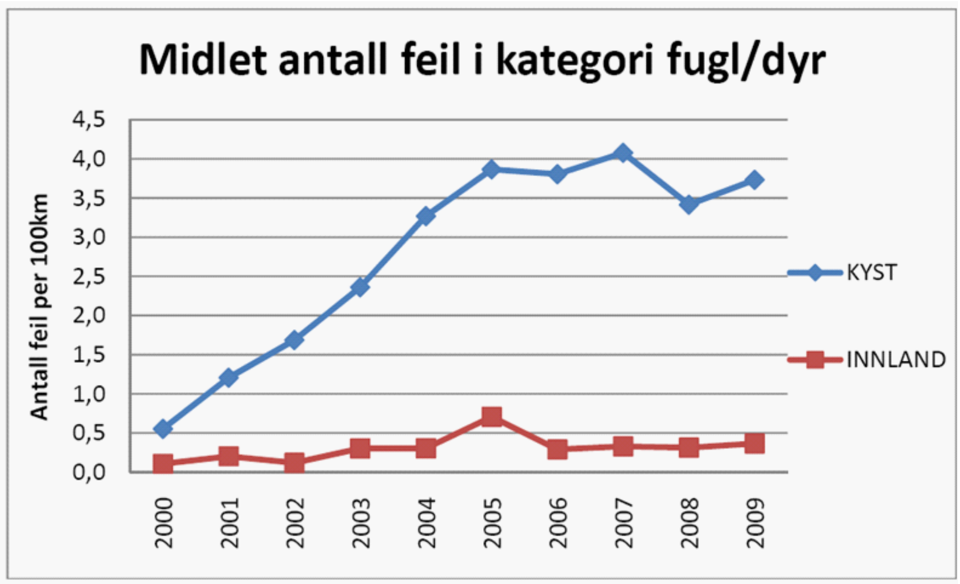


Figure 13b. *Number of errors (***antall feil***) where animals are (confirmed or suspected) the underlying cause in the groups hinterland (***innland***) and coastal areas (***kyst***).*

10 Eagle owl population impact of power-line induced mortality

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.

Figure 14. *Several of the breeding eagle owls in the study area are ringed. On this bird the ring is visible on its right leg*. Photo: Karl-Otto Jacobsen ©

10.1 Description of work and research methods

The Norwegian eagle owl population has experienced a steep decline since the 1950ies. The number of breeding pairs is now estimated to be somewhere between 408 and 658 (Jacobsen et al. 2008). The species is categorised as endangered (EN) on the Norwegian Red List (Kålås et al. 2010). 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 placed at the office of 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 and Jacobsen 2008). Solværøyene and Lovund have at most 26 breeding pairs of eagle owls, and the entire Lurøy population could probably consists of 40-50 pairs in good periods. Over the last twenty years members of the Rana Zoological Society have recorded 30-40 dead eagle owls in connection with utility structures, and about 90% of the specimens were most likely killed by electrocution, the rest by collisions (Espen R. Dahl pers. comm.). This makes the area suitable for e.g. mitigation experiments. We have cooperation with Hedmark University College, who has provided information about eagle owl breeding success and collected feathers for DNA analyses.

The study has 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 find electrocuted eagle owls
3) Collecting feathers of eagle owls from the nests for DNA analysis to obtain 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 owl and evaluate how the mortality of adult birds affects the breeding success.

10.2 Activities and findings

The Eagle owl had a very low breeding success in the study area in 2010, probably due to a low vole year. Very few young were available for study because of that, and only one juvenile eagle owl was equipped with a GPS satellite transmitter in 2010. Its positions in relation to power pylons are shown in **Figure 18**a. The bird eventually dispersed in the autumn (October 11), and its movements until October 20 are shown in **Figure 18b**, together with a juvenile that dispersed in the October 25, 2009.

Attempts to catch adults near the nests were unsuccessful. However, the male which was caught and equipped with a solar cell transmitter in 2009, gave GPS signals from June 17 to July 10 2010, and Argos signals from April 29 to September 30. Only the GPS signals are accurate enough to analyse the use of pylons. A close-up of his positions in the vicinity of a local power-line in 2009 and 2010 are shown in **Figure 17**, together with the positions of its female partner from 2009. Only the female had positions that were probably obtained from pylons (three), indicated by arrows. Another adult female (not shown) caught in 2009 had one position that was attributed to have come from a pylon. Hence, of the 299 GPS positions obtained from adults, only four (1.3%) were believed to be attributed to pylons (positions closer to pylons than 10m), but the figure must be taken with great caution, due to low sample-size, few individuals and lack of field verification. If the number was representative, it would involve pylon-perching of close to 120 hours per year per individual, which would involve a certain degree of risk.

Eagle owl feathers for future DNA analyses were sampled. Searches were carried out beneath all power lines and pylons in the study area (**Figure 16**) to find carcasses of eagle owls and other birds. One eagle owl and two white-tailed eagles were found killed by electrocution. An overview of all the dead birds found beneath power lines/pylons during the period 2008-2010 is given in **Table 2**, and photos of some of these poles are shown in **Figure 19 a-j**.

Figure 15. *Eagle owls often use pylons for hunting. Photo: Karl-Otto Jacobsen ©*

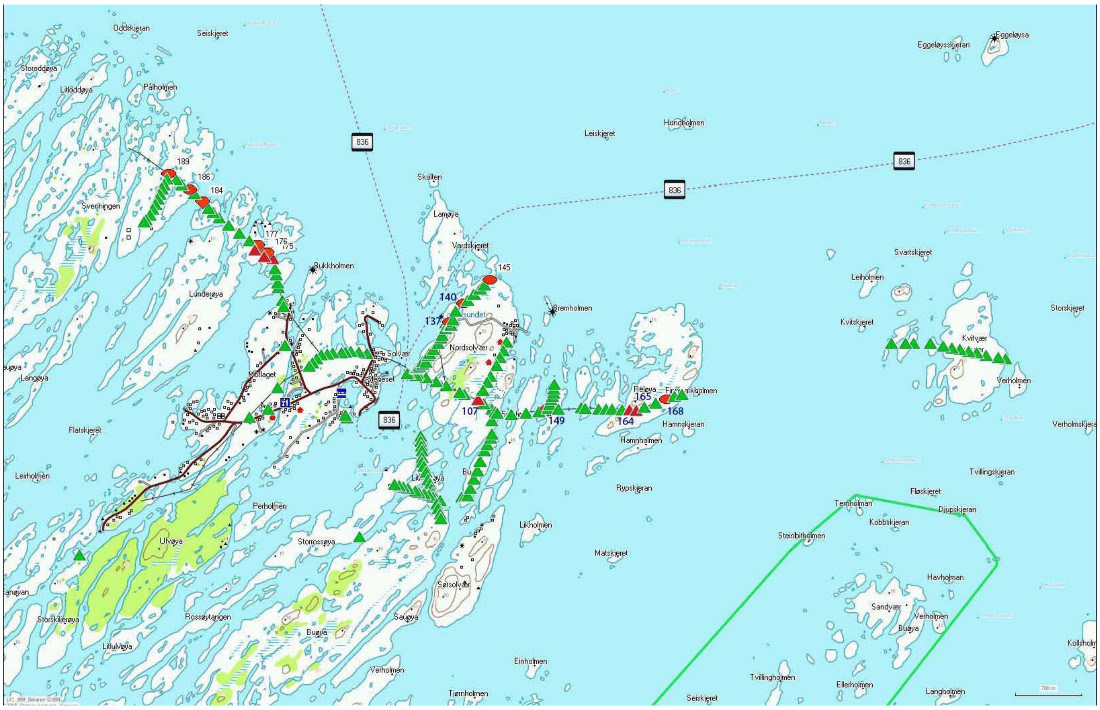


Figure 16. *Map over parts of Solværøyene with pylons shown as triangles. Pylons where carcasses have been found in red triangles or circles.*

Table 2. *All the bird* carcasses *and remains found beneath power lines/pylons in the period 2008-2010. Photos of some of these poles are shown in* **Figure 19 a-j**.

Pylon no.	Type of pylon	2008	2009	2010
107	Debranching			1 White-tailed eagle (adult)
137	Cable debranching		1 Black-backed gull	
140	Metal cross-arm			1 Greylag goose (line)
145	Cable debranching	1 gull sp.(Black-backed/Herring gull.)	2 Hooded crow	1 Hooded Crow, 1 Raven, 1 gull sp.(Black-backed/Herring gull.)
149	Pole-mounted transformer	1 Eagle owl (bones)		
164	Pin isolator			1 White-tailed Eagle (juv.)
165	Pole-mounted transformer	2 White-tailed eagle	1 White-tailed eagle (re-mains)	
168	Double pin isolator	1 Greylag goose		
175	Double pin-isolator		1 White-tailed eagle (old remains)	
176	Cable debranching	1 Eagle owl (from previous winter), 2 Hooded crow	1 White-tailed eagle (old remains)	
177	Double pin-isolator	1 White-tailed eagle	1 Eagle owl (bones)	1 Eagle owl (from previous winter)
184	Cable debranching	1 Eagle owl (bones)		
186	Pin-isolator			2 Hooded crow
189	Pole mounted transformer			1 Hooded crow

Table 3. *Bird carcasses and remains found beneath power lines/pylons in the period 2008-2010 sorted by year and species/group.*

Art	2008	2009	2010	Total
Eagle owl	3	1	1	**5**
White-tailed eagle	3	3	2	**8**
Crow/Raven	2	2	4	**8**
Gulls	1	1	1	**3**
Greylag goose	1		1	**2**
Sum per year	**10**	**7**	**9**	**26**

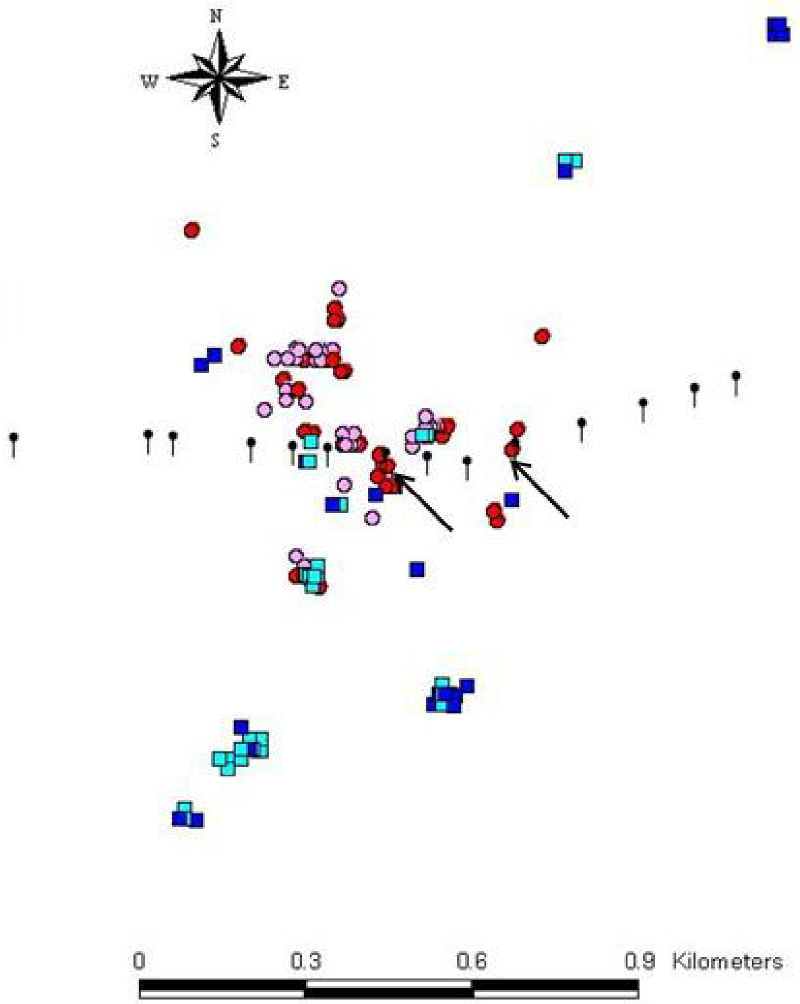


Figure 17. *Close-up of GPS positions of the adult breeding pair. Male 2009-2010 (blue squares) and female 2009 (red circles). Light colours = day positions 06:00 -19:00), dark colours = night positions (20:00 - 05:00). The power-poles are shown in black. The circles indicated by arrows show where the birds probably have been perching on poles (being within the GPS error margin of +/- ca 10m)*.

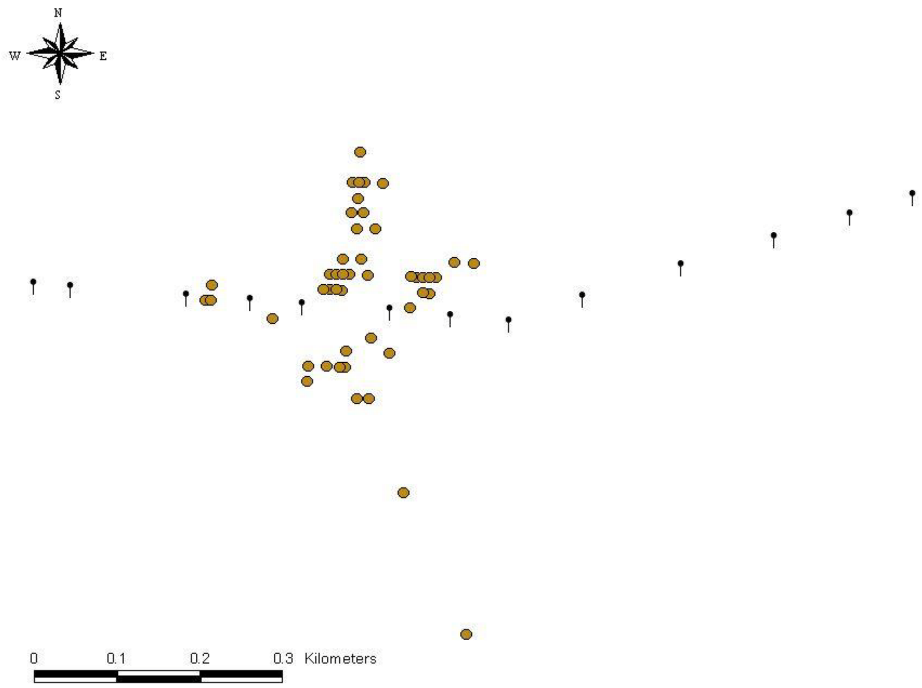


Fig 18a. *Positions of a juvenile eagle owl in relation to power-line pylons in 2010*.

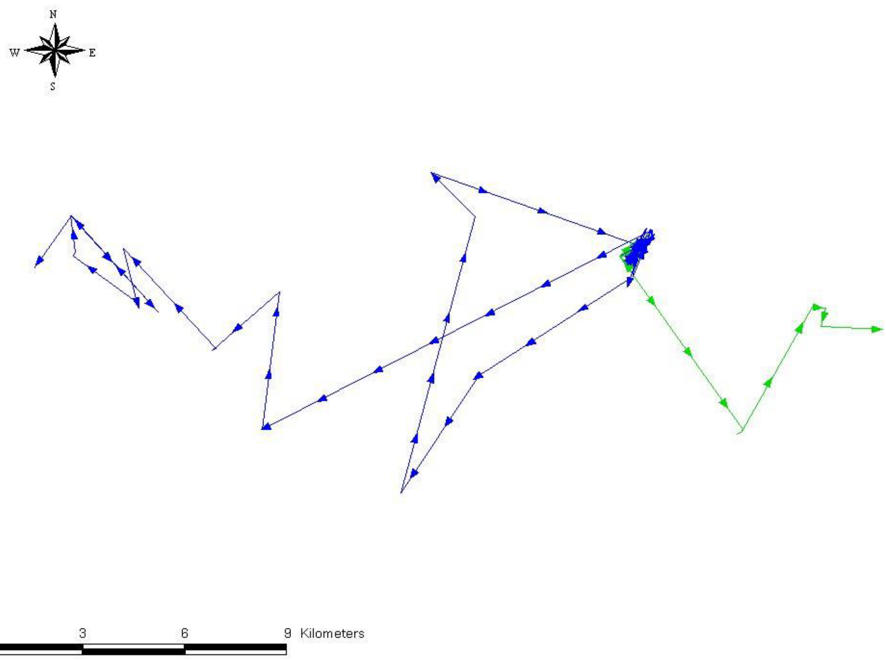


Figure 18b*. Dispersal of juvenile eagle owls, one in 2009 (blue) and one in 2010 (green).*

Figure 19a*. Pylon no 107. Debranching.* Photo: J.O. Gjershaug.

Figure 19b. *Pylon no 137. Cable debranching*. Photo: J.O. Gjershaug.

Figure 19c. *Pylon no 140. Metal cross-arm.* Photo: J.O. Gjershaug.

Figure 19d. *Pole no 145. Cable debranching.* Photo: J.O. Gjershaug.

Figure 19e. *Pole no 149. Pole-mounted transformer.* Photo: J.O. Gjershaug.

Figure 19f. *Pole no 165. Pole-mounted transformer.* Photo: J.O. Gjershaug.

Figure 19g. *Pole no 176. Cable to ground-mounted transformer.* Photo: J.O. Gjershaug.

Figure 19h. *Pole no 177. Double pin-isolator.* Photo: J.O. Gjershaug.

Figure 19i. *Pole no 184. Cable debranching.* Photo: J.O. Gjershaug.

Figure 19j. *Pole no 186. Pole-mounted transformer.* Photo: J.O. Gjershaug.

11 Electrocution survey on Smøla

11.1 Backgound

During the last years we have received several reports on white-tailed eagles (WTE) found dead as a result of electrocution at the power-lines on Smøla. Other species have also been reported as electrocution victims. Through the project BirdWind (Bevanger et al. 2009) we aim to describe in detail the dynamics of the WTE population on Smøla, a central part of this is to monitor the mortality in the population, as well as the mortality causes. Thus, it was of great interest to investigate to what extent the WTE suffers from electrocution mortality. Although this study not is a formal part of the OPTIPOL project, it fits well into several parts of the project objectives, and we find it useful to report the findings here.

11.2 Description of work and findings

We received GIS files of the Smøla grid from the grid owner, NEAS (Nordmøre Energiverk AS). The different pole designs/structures in the grid were classified with the help of local employees in NEAS. In total there are 1498 poles in the municipality of Smøla, we selected 740 out of these for our electrocution survey (**Figure 20**). The selection was based on what pole designs that we assessed as dangerous, based on experiences from other studies (e.g. APLIC 2006). Poles in the survey selection were poles with transformers (87), swithers (34), junctions (36), top-mounted insulators (571) and switchers and junction combined (12).

The first survey was conducted during November 9th and 10th 2009, 50 of the poles in the selection were surveyed the 4th of April 2010 due to the ground being covered in snow. Bird carcasses found during the survey have accumulated over several years. Therefore all bird carcasses that were found were removed. This was done to be able to calculate species-specific mortality per year. A new survey will be conducted during the winter 2010/2011.

A total of 142 birds (**Figure 21**) from a number of species were recorded beneath the selected poles. This includes two individuals of WTE and 1 golden eagle found by others and reported to us during the last two years. A total of 9 WTE were recorded, one of these was found outside our survey selection.

There is a considerable difference in the electrocution risk at the different pole designs, with switchers, junctions and transformers being the designs with highest numbers of electrocution victims per pole (0.53 – 0.62 birds/pole). The pole design with pin insulators has the lowest number of electrocution victims per pole (0.08 birds/pole). A continuation of this study will give further insight into the electrocution risk at the different pole designs.

Some of the poles had several electrocution victims (**Figure 22**), and a high proportion of the total victims were found at a small proportion of the poles in the grid. It is therefore likely to be more factors than pole design only defining the electrocution risk at Smøla, such as habitat type, topography, available perching sites etc.

In the BirdWind project a total of ca. 60 WTE young have been equipped with satellite transmitters (Bevanger et al. 2010); data from these transmitter exceeds 42000 GPS fixes throughout Smøla. These data will be combined with the GIS data on the power line grid to investigate to what extend the birds are using the power-line poles for perching. Hopefully, this will further strengthen our understanding of what factors that is important in variation in electrocution risk in birds.

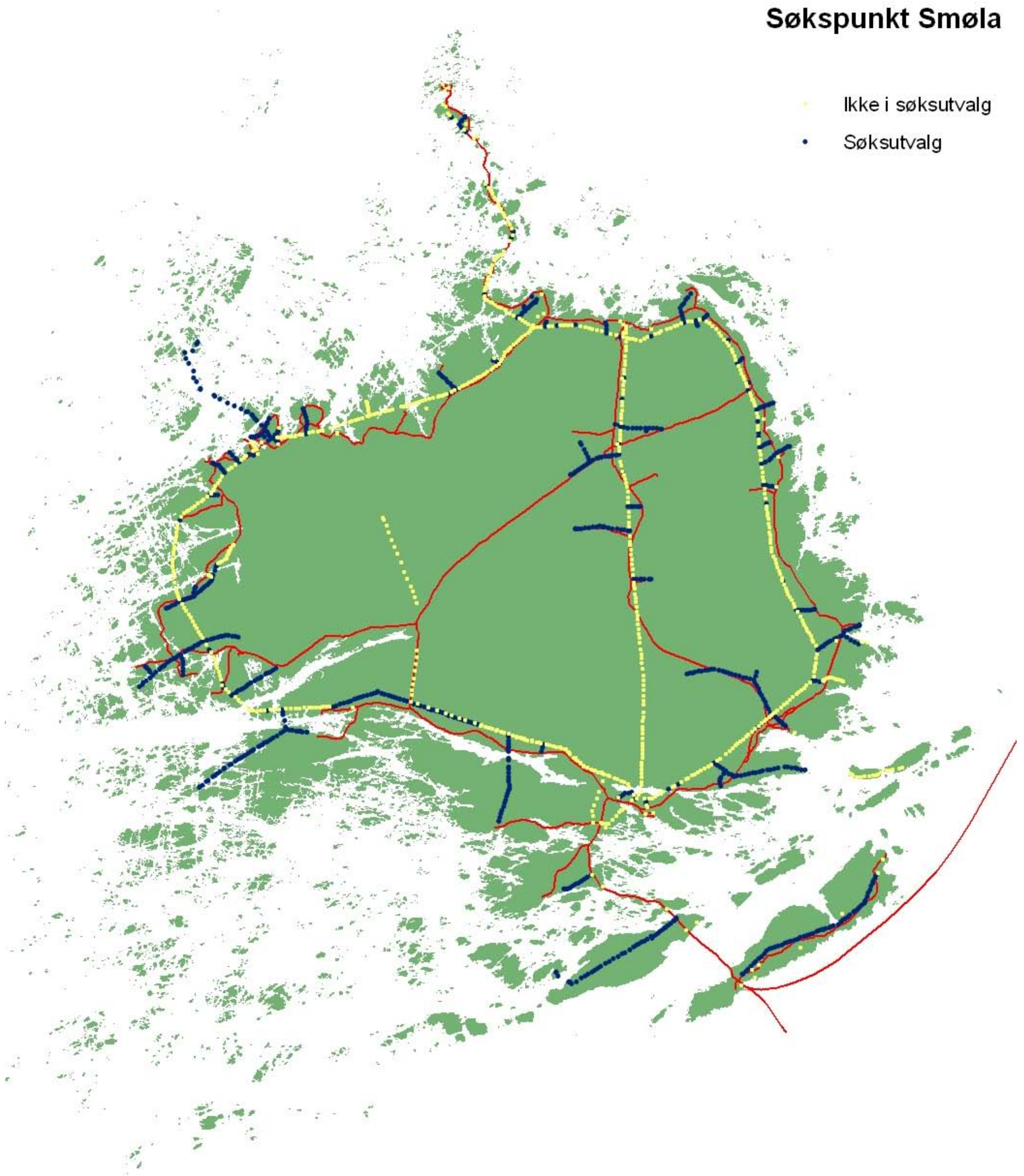


Figure 20. *Power line grid on Smøla with the poles in the survey selection in blue. The poles outside our selection in yellow. Roads are indicated with red lines.*

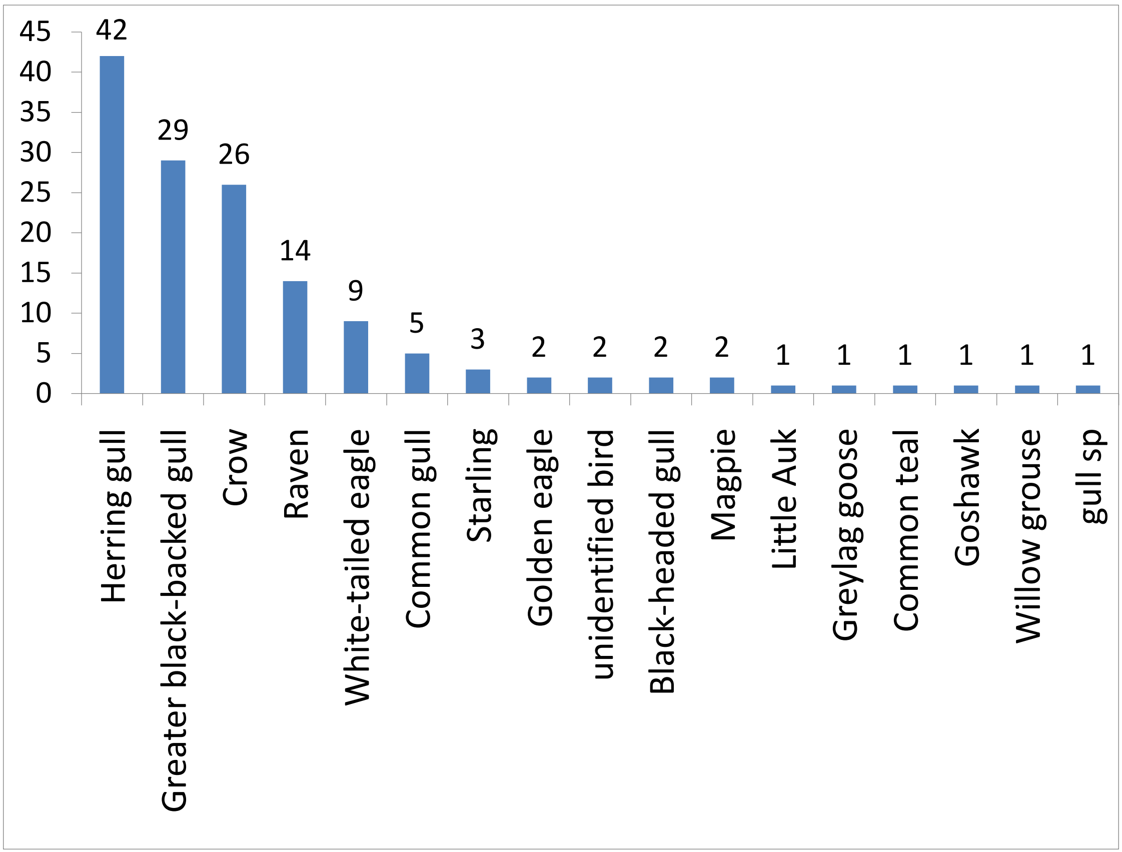


Figure 21. *Number of individuals per species recorded as electrocution victims at Smøla during our first survey. Some of the smaller species (e.g. little auk, teal) could have been carried there by raptors using the poles for perching.*

Table 3. *Number of poles in each structure class, number of birds found at the different structures and the number of birds per poles at the different structures. * 4 out of the total 142 birds found are removed from this table, as there are uncertainties to which structure class they belong.*

	All	Transformer	Switcher	Junction	Top-mounted insulator	Switcher & junction
Number of poles	740	87	34	36	571	12
Actual number of birds	138*	49	21	19	47	2
Actual number per pole	0.19	0.56	0.62	0.53	0.08	0.17

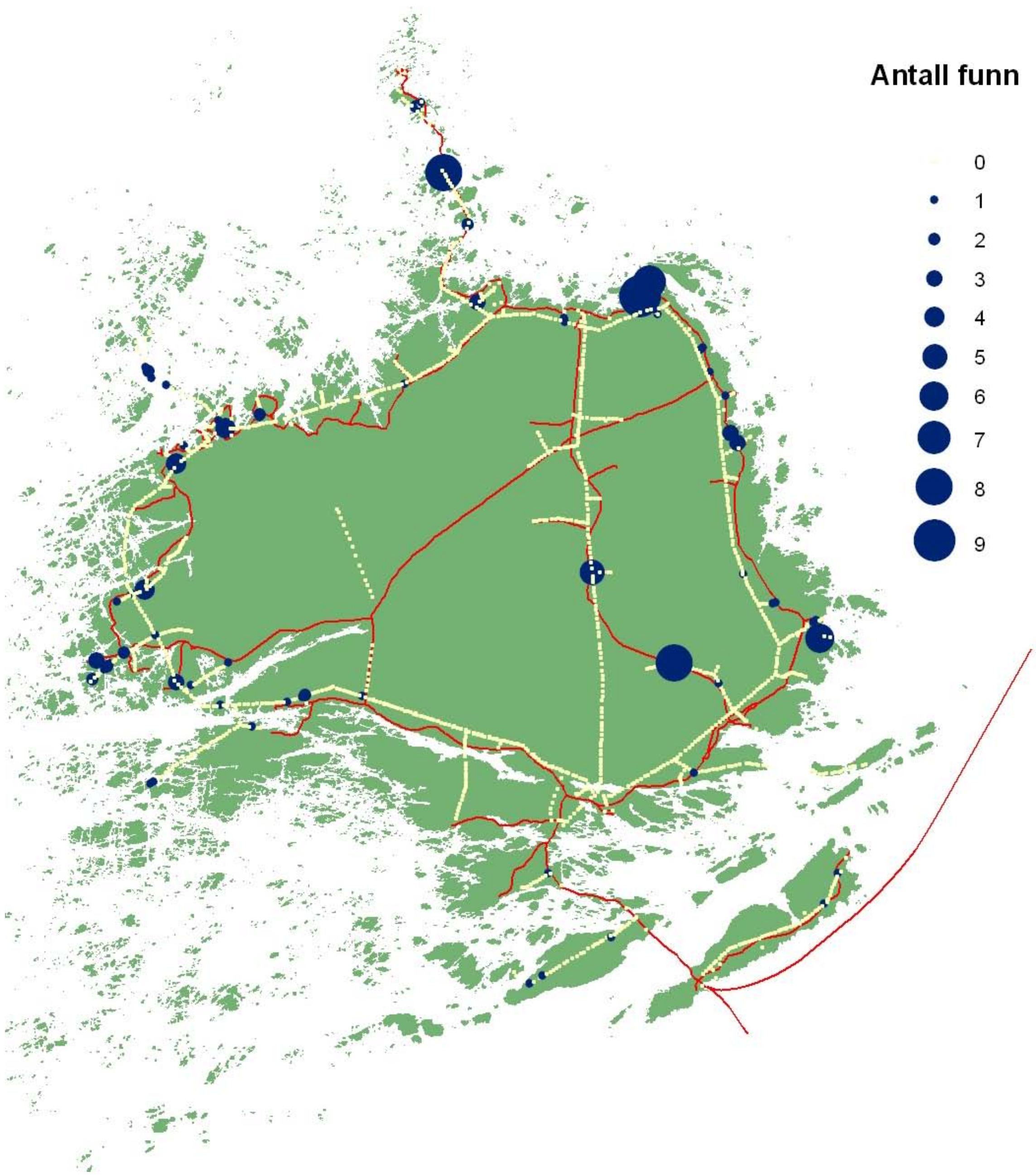


Figure 22. *The locations of the poles with electrocution victims in blue circles. The number of victims is represented with the size of the circles.*

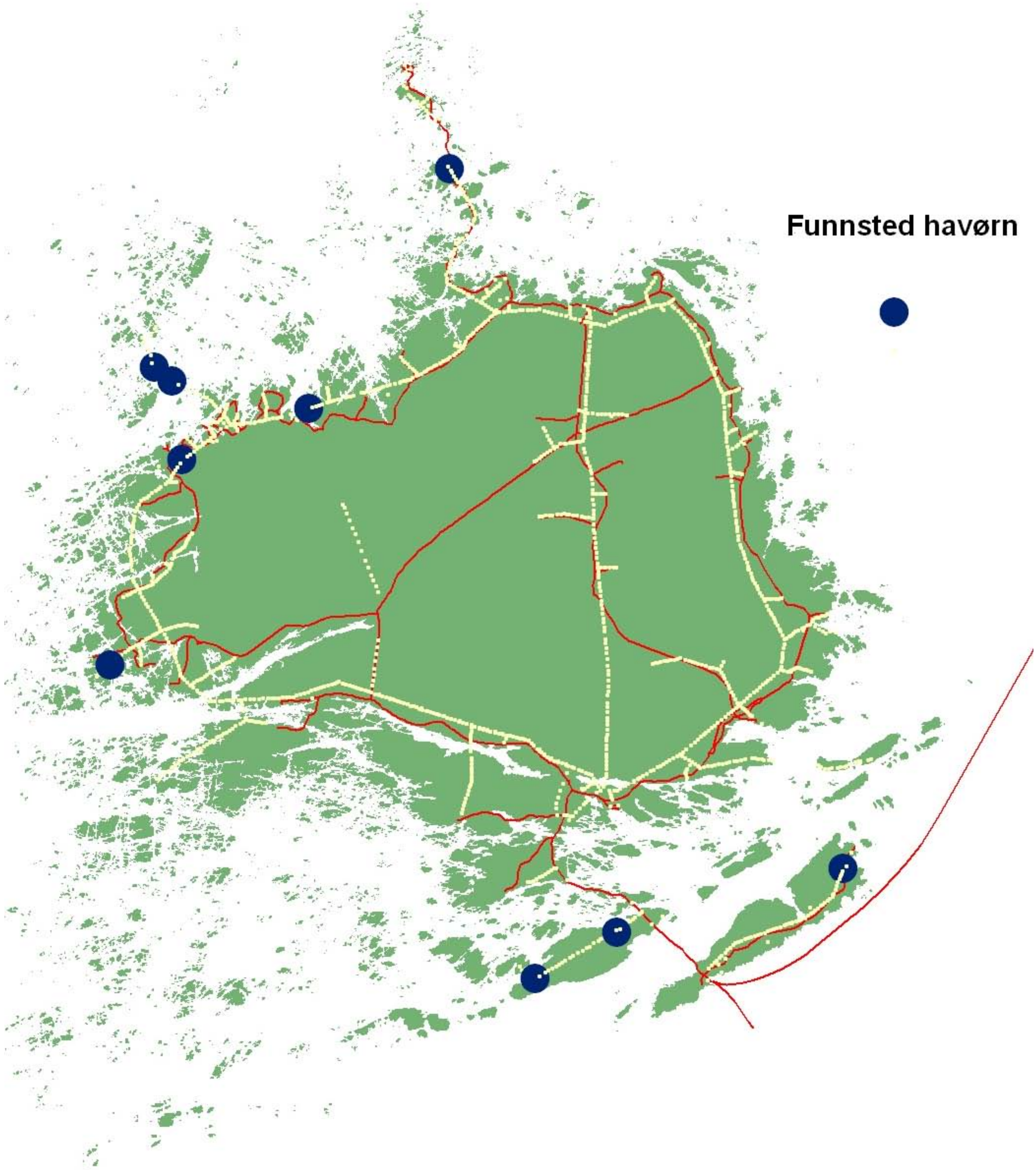


Figure 23. *Locations of the WTE found as electrocution victims in blue circles.*

12 Publications, lectures, media coverage

12.1 Publications

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.

12.2 Lectures and conference participation

Bartzke, G. Effects of power-line rights-of-way (ROW) vegetation management on habitat use, movement and behaviour of wildlife. Lunchseminar at NINA. Trondheim 08.04.2010

Bartzke, G. Effects of power line rights-of-way (ROW) vegetation management on habitat use, movement and behaviour of wildlife. CEDREN PhD meeting. Trondheim 14.04.2010

Bartzke, G. Presentation of PhD project. Effects of power-line rights-of-way (ROW) vegetation (management) on habitat use, movement and behaviour of wildlife. Large Herbivore Research Group (NTNU). Trondheim 19.04.2010

Bartzke, G. Potential of power-line rights-of-way as habitat resources for moose *(Alces alces)* and other wildlife. CEDREN Scientific Committee. Trondheim 27.10.2010.

Bartzke. G. Power lines as wildlife biotopes. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Bevanger, K. NINA, BirdWind og OPTIPOL. Møte med OED. Trondheim 16.11.2010.

Bevanger, K. BirdWind & OPTIPOL. CEDREN Scientific Committee. Trondheim 26.10.2010.

Bevanger, K. OPTIPOL. Seminar om FoU på bærekraftig energiproduksjon, CEDREN og DNs Energiteam. Trondheim 08.01.2010.

Bevanger, K. project status, new applications etc. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Bevanger, K. Immediate actions to reduce mortality among birds due to power lines. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Brøseth, H. Power lines as a mortality factor for tetraonids. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Dahl, E.L. Bird electrocution recordings along the Smøla grid. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Hanssen, F. A. A "least-cost path" GIS-based application for optimal routing of power lines. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Husdal, MM. Status on the National Action Plan for the eagle owl. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Gjershaug, J.O. Status on the eagle owl project atSleneset. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Kvaløy, P. A national database for data recording of mortality among birds due to power lines. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

May, R. Optimal design and routing of power lines; ecological, technical and economic perspectives (OPTIPOL). CEDREN generalforsamling, Trondheim 06.05.2010.

Meås, R. How to get a dog trained to be interested in birds killed in connection to power lines? OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Refsnæs, S. Technical possibilities and constraints to reduce the bird mortality in connection to power lines. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Stokke, S. NINA, OPTIPOL. Presentasjon for CEDREN Reference Group - BirdWind og OPTIPOL. Trondheim 19.10.2010.

12.3 Coverage in public media

Bladet Vesterålen – 23.12.2009. Andøy er på rypetoppen. Kjetil Bevanger.

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Gjershaug, J.O. & Jacobsen, K.-O. 2009. Hubro i Lurøy og kraftforsyning. NINA Minirapport 251. 16 s.

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

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Kålås, J.A., Viken, Å., Henriksen, S. and Skjelseth, S. (eds.). 2010. The 2010 Norwegian Red List for Species. Norwegian Biodiversity Information Centre, Norway.

14 Appendices

Appendix 1. *The OPTIPOL Annual Meeting Program 2010.*

NINA
Norsk Institutt for naturforskning

Møteinvitasjon

Brukermøte OPTIPOL 2010 – 22. november kl 0900-1600. Rica Hell hotell, Stjørdal

Som tidligere kommunisert samles vi til brukermøte på Rica Hell hotell mandag 22. november. Intensjonen med møtet er å presentere status for prosjektet og diskutere veien videre. De enkelte delprosjektene har hatt forskjellig fremdrift, men de fleste er nå igangsatt, så litt har vi å snakke om.

0900-0915	Velkommen. Prosjektstatus; nye søknader m.m. (Kjetil Bevanger)
0915-0945	En "least-cost path" GIS-basert applikasjon for optimalt trasevalg av kraftledninger; (Frank Hanssen/Roel May)
0945-1015	Kraftledningsgater som viltbiotoper. Gundula Bartzke presenterer sitt PhD-prosjekt
1015-1035	Kaffepause
1035-1055	Kraftledninger og dødelighet hos skogsfugl. Har det noen betydning? (Henrik Brøseth)
1055-1110	Nasjonal database for registrering av fugl drept pga. kollisjon/elektrokusjon (Pål Kvaløy)
1110-1130	Hvordan få en hund til å finne kollisjonsdrepte fugler? (Roger Meås)
1130-1215	Lunsj
1215-1235	"Strakstiltak" for å redusere kollisjons- og elektrokusjonsfare (Kjetil Bevanger)
1235-1250	Handlingsplan for hubro – status (Mia Marthinus Husdal, FM i Nordland)
1250-1315	Hubro på Sleneset. Prosjektstatus (Jan Ove Gjershaug)
1315-1400	Tekniske muligheter og begrensninger av tiltak, som kan redusere faren for fuglekollisjoner eller elektrokusjon (Steinar Refsnæs)
1400-1420	Kaffepause
1420-1440	Kartlegging av elektrokusjonsfare på Smøla (Espen Lie Dahl)
1440-1600	Diskusjon. Veien videre – kurskorreksjoner?

Trondheim 15.11.2010

Kjetil Bevanger

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Norwegian Institute for Nature Research
NINA head office
Postal address: NO-7485 Trondheim, NORWAY
Visiting address: Tungasletta 2, NO-7047 Trondheim, NORWAY
Phone: + 47 73 80 14 00
Fax: + 47 73 80 14 01
Organisation number: NO 950 037 687 MVA

www.nina.no

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