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NINA Rapport

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

Final Report; findings 2009 – 2014

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

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CEDREN – Centre for Environmental Design of Renewable Energy: Research for technical development and environmental impact of hydro power, wind power, power lines and implementation of environment and energy policy.

SINTEF Energy Research, the Norwegian Institute for Nature Research (NINA) and the Norwegian University of Science and Technology (NTNU) are the main research partners. A number of energy companies, Norwegian and international R&D institutes and universities are partners in the project.

The centre, which is funded by The Research Council of Norway and energy companies, is one of eleven Centre for Environment-friendly Energy Research (FME). The FME scheme consists of time-limited research centres which conduct concentrated, focused and long-term research of high international quality in order to solve specific challenges in the field of renewable energy and the environment.

CEDREN Centre for Environmental Design of Renewable Energy

FME Centre for Environment-friendly Energy Research

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FORSIDEBILDE
Injured capercaille female due to collision with a transmission line. Photo: Roger Meås

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Summary

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OPTIPOL was designed by NINA in early 2008, with a particular focus on power lines and wildlife interactions. As soon as CEDREN was approved as a CEER, OPTIPOL became an integrated part of the centre. The overall objectives of OPTIPOL have been to contribute to an environmental friendly future development of the grid by developing predicting tools for optimal routing of power lines, and assess technical and economic solutions to minimize conflicts with wildlife and habitat conservation. It has been a project focusing on applied research topics, and several user groups (energy industry, environmental and energy management authorities) have been closely involved during the project period, both formally and informally. The project activities have been reported through four annual reports, and the content in the present report is restricted to give an overview of the work package activities and summarize their findings.

The work in OPTIPOL has been subdivided into the following focal areas and work packages:

- **WP1. Power line ROW as habitat resources for moose (*Alces alces*) and other wildlife,** with an objective to assess how and why different wildlife species use deforested areas below power lines and evaluate possible positive and negative effects of power line ROW´s. The target species has been moose (*Alces alces*).
- **WP2. Capercaillie (*Tetrao urogallus*) and black grouse (*Tetrao tetrix*) population responses to power-line induced mortality,** with an objective to assess population impact of bird mortality due to collisions with power lines, relative to other human-related mortality factors (primarily hunting) in gallinaceous birds (with capercaillie and black grouse as model species).
- **WP3. Bird collision hot spots,** with an objective to analyse old and new data on bird collisions with power lines to see how the collisions are distributed, i.e. if the collisions are distributed randomly or if there are “hot-spots” with particularly many collisions. Using GIS modelling the aim is to identify possible ecological high-risk factors for bird collisions, i.e. site-specific factors connected to topographic characteristics, including vegetation structure, season, weather and light conditions.
- **WP4. National database for reporting on dead birds**, with an objective to develop and implement a SQL-server spatial database for storing and retrieval of dead-bird data.
- **WP5. A Least Cost Path (LCP) toolbox for scoping and optimal routing of power lines**, with an objective to develop a LCP-desktop GIS toolbox for optimal routing of transmission lines based on social, ecological, economic and technological criteria.birds are colliding
- **WP6. Power-line camouflaging**, with an objective to assess, based on available literature, the possibilities for increased collision hazard to birds by making the power line structures less visible to humans, and if the technical solutions may reduce the security for a safe energy supply.
- **WP7. Mitigating effect of power-line marking and modifications**, with an objective to review available literature on technical modifying solutions and assess their effectiveness to mitigate bird collisions and electrocution, and if the technical solutions may reduce the security for a safe energy supply.
- **WP8. Guidelines for technical solutions to mitigate power-line induced mortality to birds, and if the technical solutions may reduce the security for a safe energy supply.** WP6, 7 and 8 is closely connected, and has been reported in separate reports (see Bevanger & Refsnæs 2013 a, b and references therein).
- **WP9. Eagle owl population impact of power-line induced mortality**, with an objective to assess eagle owl mortality and population impact due to utility structures, identify high-hazard electrocution structures, and test effectiveness of design modifications of these.

Some main conclusions and findings are highlighted below.

WP1. Power lines could disturb ungulates being artificial structures emitting noise and electromagnetic fields. Our analyses suggests that moose do not avoid ROWs, and frequently use them for browsing opportunities. Moose seem to use much time alongside ROWs or other edges in the study area, possibly due to forage availability and better cover than in open areas. However, moose seem to avoid roads and especially roads paralleling rivers.

Forest ungulates could benefit from browsing opportunities in the power-line clear felled corridor if they are managed to provide abundant forage and sufficient cover. Most benefits may be expected when power lines are routed through old coniferous forests providing little food. Selectively clearing trees reaching heights of five meters could ensure continuously high browse availability without the removal of cover. Alternatively, cutting deciduous trees at a height of one meter or hinge-cutting instead of full removal could shorten the period of low browse availability after clearing. However, this needs further investigation. Power-line ROW may facilitate access for hunters and provide hunting grounds for predators along forest edges. As a precaution, construction of power lines should be avoided in areas and during times of calving to prevent inference with reproduction.

More research is needed to find out if power lines increase avoidance and barrier effects in relation to other human features and how the width of the clear-felled corridor may influence crossings and edge effects. To establish a causal relationship between the construction of power lines and potential avoidance, before-after-impact-control studies are recommended in combination with surveying other disturbance indicators and availability of browse.

WP2. Line transects and DNA-analyses have provided data for the population size of black grouse and capercaillie in March-April, and regular searches with a trained dog have been performed to find collided birds in the power-line corridor. In 2011 the population in the study area was estimated to be 86 black grouse (3.0 birds/km^2) and 34 capercaillie (1.2 birds/km^2). 29 sites with bird/bird remains from collision victims was identified. DNA analysis was used to identify 19 different individuals from 5 species among the bird/bird remains, among others 4 capercaillie and 4 black grouse. In 2012 a total of 29 different black grouse and 23 capercaillie specimens were identified from the DNA samples. The population in the study area was estimated to be 70 black grouse (2.4 birds/km^2) and 56 capercaillie (1.9 birds/km^2). 20 sites with bird/bird remains from collision victims in the study period were identified. DNA analysis was used to identify 14 different individuals from nine species among the bird/bird remains, among others 3 capercaillie and 1 black grouse. In 2013 a total of 63 different black grouse and 15 capercaillie specimens were identified from the DNA samples collected. The population in the study area was estimated to be 99 black grouse (3.4 birds/km^2) and 24 capercaillie (0.8 birds/km^2). As of October 24 2013 a total of 12 search patrols for dead birds had been conducted in the third study year, and 19 sites with bird/bird remains from collision victims have been identified. DNA analysis identified 13 different individuals from eight species among the bird/bird remains, among others 1 capercaillie and 7 black grouse. The weather conditions made further DNA-data sampling in spring 2014 impossible. During April-27-30 lek recordings were carried out along the power line section and 5 black grouse leks were found. One last search trip to look for collided birds will take place week 21. The last DNA analyses of dead birds found will be made in early autumn.

DNA analyses based on dropping collection seem to provide reliable capercaillie and black grouse population estimates within a practicable timeframe and reasonable costs. The method would also reduce the possibility for overestimating the population size and the number of collision victims. There are several biases associated to dead bird collection in power-line corridors, and sometimes it is difficult to decide whether separate feather and bird remains come from same or different fatalities. With DNA analyses the subjectivity is eliminated. The overall (preliminary) conclusion with respect to population impact is that the recorded mortality for capercaillie in 2011-2013 are estimated to reduce the population size between 4.2-11.8 percent, and 1.4-8.1 percent for black grouse. This additional mortality should be taken into account when e.g. hunting licenses are issued.

WP3. Due to low capacity among the NINA GIS experts, the analysing part of the project is delayed, and the result will be published at a later stage.

WP4. Although a functional prototype of a database was finalised in 2009 NINA addressed the possibilities to co-operate with The Norwegian Biodiversity Information Centre (NBIC) in early 2010. The NBIC already had a species observation portal – *www.artsobservasjoner.no* - having become a popular web site and accessed by people contributing with hundreds of observations daily. By making some adjustments of the activity list for death causes in *www.artsobservas-joner.no* it was possible to use the NBIC observation portal to collect data on dead birds as well. The number of reported bird casualties due to collisions with power lines and electrocution has been rather stable, with 25 both in 2011 and 2012, and 33 in 2013.

WP5. The LCP toolbox is a useful planning tool when applied at an early planning stage in order to scope environmental impact assessment, reduce potential stakeholder conflicts and make the decision process more transparent to the public. In their power-line project cycle, Statnett consider OPTIPOL LCP to be a useful tool during the initial feasibility study and the public inquiry phase prior to the governmental designed impact assessment program.

The OPTIPOL LCP Toolbox has been presented at several international conferences on impact assessment, societal impacts of improved environment, and power-line right-of-way management and geospatial technology. Feedbacks from among others the EU Commision (DGE Environment) has underlined particularly the potential of the OPTIPOL LCP tool as an important contribution to holistic decision making, democratization, user participation and increased efficiency in connection to huge development processes. Great interest have also been expressed regarding implementation of the OPTIPOL LCP methodology from STATOIL (routing of offshore pipelines), The European Incoherent Scatter Scientific Association- EISCAT (siting of new radar facilities in northern Scandinavia) and the County council of South Trøndelag (land use planning and siting of wind-power plants).

The LCP methodology will be further developed and adapted to least cost siting (LCS) as a part of the CEDREN Common Activities (2014-2016). In addition NINA and a wide range of international partners have now implemented the OPTIPOL LCP results in several research applications focusing on siting of fish farms (Horizon 2020) and siting of wind energy (European Economic Area Grants for Czech Republic, Romania and Lithuania).

OPTIPOL LCP 2.0 is currently operational only at a desktop platform, and will consequently not be easily accessible for contemporary use (e.g. at an early stage of the announcement phase of grid development). OPTIPOL LCP 2.0 is based on standard ESRI technology being directly compatible with the ESRI ArcGIS Server Platform. To further develop and test the method and the tool and the criteria used, it is important to find a cooperating partner. The project cooperation should focus on technology and methodology development and processes connected to increased user participation.

WP6/WP8. This desktop study has reviewed the literature on bird vision to find possible evidence for how different types of camouflaging may impact the bird collision hazard, and how different type of colour coating and treatment of the wires may impact technical aspects like crevice corrosion.

The mammalian and bird eyes have many common features, and anatomy and function is relatively well studied and understood. It is, however, not correct to assume that different species perceive their environments in the same way. With respect to bird colour vision, depth vision and vision acuity, there are several unanswered questions when it comes to power-line camouflaging. For birds to achieve an optimal detection of a power line, it is important to optimize the contrast of the line against the background colour. Several scientists assume that some bird species have an advanced ability to separate colours in the yellow part of the light spectre. It seems likely that some green and yellow colours, particularly if these at the same time have an UV contribution, contrasts against a natural green background. To reduce the contrast between an air wire and the background, e.g. by matting the blank surface of a FeAl-wire with a black or a grey-blackish colour, will probably increase the collision risk for some bird species. To make conductors and earth wires as visible as possible from an avian perspective, in general it seems best to localise power lines in a way that optimizes the contrast against the background. The seasonal variations in Norway make an environmental colour cycle – from white in the winter through brownish-black in the spring to green in summer and yellow-red in the autumn. Thus, regardless of camouflaging colour used, there will be periods when the power lines will be quite visible.

In exposed coastal areas there is a high risk of crevice corrosion beneath a poor adhesive coating. Coating applied after the group of wires has been spun around the central core has a tendency to hamper drainage in the line. Thus, the coating promotes internal corrosion between the filaments and the filament layers, particularly on the lines lowest point. Matted or primed camouflaged power lines seem to do well in coastal environments with low corrosiveness. The emission factor **ε** is dependant of the surface structure of the line. By increasing the emission factor, the cooling effect can be increased due to emitted heat, and the capacity of current transfer is increased by approximately 5 %. An isolating coating on the camouflaged line can result in contact problems and breakdown, and must be considered during installation and selection of binding posts. Immediately prior to installation of clamps and splices, the contact surfaces must be treated with e.g. a steel brush or emery cloth. Apart from that, a thin layer of grease should be applied to the contact surfaces. This will reduce the oxide growth and seal the contact areas against water penetration and pollution which can induce corrosion.

WP7/WP8. This desktop study has reviewed the literature on mitigating measures to reduce bird collision hazard with power lines and electrocution, and how different types of devices and modifications may impact power supply security.

Bird collisions with power lines and electrocution are strongly species-, site- and seasonal-specific accidents. It is important that future research becomes more site- and species-specific when approaching these problems and that the mitigating measures are based on facts: 1) what are the target species. i.e. which ones are the most vulnerable; 2) what is the best design when it comes to marking devices to reduces the collision frequencies among the target species; 3) what are the success rate or likelihood to reduce the mortality of the target species when it comes to economic investment of power-line marking? Such knowledge will make it easier to argue for the importance of mitigating measures, be it environmentally or monetarily. Knowledge on population consequences of the additional mortality due to utility structures is more or less none existing, and will be a particularly important topic to address for future research.

Physical enlargement of phase conductors or ground wires using some sort of marking devices has proved to reduce the collision frequencies for some species. To increase the knowledge on where and when power-line marking should be implemented, more data on species- and site-specific collision risk as well as species-specific behavioural responses are needed relative to different marking cues. For some species, there will probably be no solutions at all («no cure species») except for earth cabling. A long dusk period and a short period with light during the day, like in northern Europe and Norway during the winter (close to six months), offer minor possibilities to reduce the mortality among e.g. gallinaceous birds, being birds particularly vulnerable to collide with artificial air obstacles.

The present study have focused on the possibilities to act in connection to the existing grid, thus discussions on optimal routing of a power line through the terrain from a bird perspective, and options that only can be considered during the construction of a new power line, are omitted. There is, however, no doubt that the best mitigation and precocious steps to prevent birds from colliding with power lines are connected to an optimal routing.

Bird electrocution is mainly connected to utility structures within the grid systems below 66 kV, and the knowledge on what type of technical devices that are the most frequent electrocuting traps is substantial. Unfortunately recommendations given 25 years ago is followed up neither by the energy authorities nor the grid owners, and a main reason to a high number of electrocution accidents among birds in Norway is because well-known technology and solutions is not implemented.

Several Norwegian grid companies are logging anomalies in their grid systems frequently due to bird electrocution. The annual statistic recordings for incidences, interruptions in energy delivery and errors in the 1-22 kV grid for 2008, confirm that birds (together with a few incidences where squirrel and marten have been involved) are responsible for 13 % of all anomalies and 3 % of "not delivered energy". Average number of anomalies due to birds seems to be 8-10 times higher along the coastline compared to inland areas, however, with significant local variations within the coastal distribution grid areas. Consequently, it is important, also from the grid owner's point of view, to take actions to reduce the disruptions in stable electricity delivery caused by birds. It is, however, important that bird protection devices do not violate the security of supply in the grid systems.

Insulated metallic crossarms protects against bird electrocution as well as reduces short outages in grids lacking a Peterson coil earthed system. The negative side is increased corrosion possibilities and lack of disengagement if the phase conductor falls down on the crossarm. Installing a bird protection system on the arching horn may also reduce the number of short outages due to earth-fault currents.

WP9. The GPS satellite telemetry study has given new knowledge on how the eagle owl may use the electric pylons during hunting activities. This has also been confirmed by use of wildlife surveillance cameras and direct observations. In an open coastal landscape as Solværøyene, pylons are frequently used by the eagle owl when hunting. The telemetry study has also given new knowledge about home-range size of adult eagle owls and dispersal of juveniles.

Extraction of DNA from feathers collected in eagle owl nests and the following DNA-analyses have been successful. However, there is still too few samples from the same territories across years for proper estimation of adult mortality rates. Hence, there is a need for further sampling of feathers. The DNA analyses will also be a valuable tool for determining to which territory different nests belong. This is important for making an accurate population estimate in Solværøyene which has a very dense eagle owl population.

The search after dead eagle owls and other birds beneath power lines and pylons has given valuable knowledge about high-hazard structures being used when mitigation measures are carried out as a following up of the eagle owl action plan.

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Sammendrag

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Prosjektskissen til OPTIPOL ble laget i 2008, og hovedvekten ble lagt på problemstillinger omkring til kraftledninger og dyreliv. Så snart CEDREN ble godkjent som et senter for forskning på fornybar, ble OPTIPOL integrert i senterets aktiviteter. De overordnede målsettingene i OPTIPOL har vært å bidra til en mest mulig miljøvennlig, fremtidig nettutbygging, bl.a. ved å utvikle et GIS-verktøy som på en oversiktlig måte kan fortelle hvilke konsekvenser vektlegging av ulike faktorer (inklusive tekniske og økonomiske) vil ha for traseføringen. Aktivitetene i OPTIPOL har vært preget av fokus på typisk anvendte problemstillinger, og flere brukergrupper (energi, industri, miljø- og energiforvaltning) har vært nært knyttet opp mot aktivitetene, både formelt og uformelt. Aktivitetene og resultatene fra prosjektet har vært fortløpende rapportert gjennom årlige rapporter (NINAs rapportserie) og innholdet i sluttrapporten er begrenset til å gi en oversikt over de ulike arbeidspakkene (dvs. delprosjektene) og de viktigste konklusjonene.

Arbeidet i OPTIPOL har vært inndelt i følgende fokusområder og arbeidspakker:

- **WP1** Kraftledningskorridorer som habitatressurs for elg og annet vilt, med målsetting om å vurdere hvordan og hvorfor ulike viltarter benytter ryddebeltet under kraftledningene, samt å evaluere mulige positive og negative effekter av slike korridorer. Hovedfokus har vært elg.
- **WP2** Populasjonsresponser hos hønsefugl (med storfugl og orrfugl som modellarter) som følge av kollisjoner med kraftledninger, sammenlignet med andre menneskeskapt dødelighet (i første rekke gjennom jakt).
- **WP3** Kollisjonspunkter for fugl langs kraftledninger («hot-spots»), med målsetting om å identifisere økologiske høyrisikofaktorer i forhold til fuglekollisjoner, dvs. stedsspesifikke faktorer knyttet til topografi, inklusive vegetasjonsstruktur, årstid, vær og lysforhold.
- **WP4** Nasjonal database for innrapportering av funn av døde fugler, med målsetting om å utvikle og drifte en database som kan lagre og gjøre tilgjengelig opplysninger om døde fugler innrapportert fra publikum.
- **WP5** En Least Cost Path (LCP) redskapskasse for optimal traseføring for kraftledninger, med målsetting om å utvikle en LCP desktop GIS redskapskasse, basert på sosiale økologiske, økonomiske og tekniske kriterier.
- **WP6** Fargekamuflering av kraftledninger, med målsetting om å vurdere (basert på en litteraturgjennomgang) hvorvidt kamuflering kan øke kollisjonsfaren for fugl og om de tekniske løsningene kan føre til redusert forsyningssikkerhet.
- **WP7** Effekter av merkemetoder og tekniske modifiseringer av kraftledninger (basert på en litteraturgjennomgang), med målsetting om å evaluere effekten i forhold til redusert omfang av kollisjoner av fugl og elektrokusjonsulykker, og om de tekniske løsningene kan føre til redusert forsyningssikkerhet.
- **WP8** Retningslinjer for tekniske løsninger for å redusere dødelighet hos fugl og om disse kan føre til redusert forsyningssikkerhet. WP 6,7 og 8 er knyttet nært sammen og er rapportert i separate rapporter.
- **WP9** Bestandseffekter av hubrodødelighet som skyldes kraftledninger, med målsetting om å vurdere om kraftledninger kan holde bestanden av hubro nede, samt identifisere kraftledningsstrukturer som er spesielt uheldige i forhold til elektrokusjon, samt teste mulig avbøtende tiltak.

Nedenfor gjengis de viktigste konklusjoner og resultater fra prosjektet.

WP1. Kraftledninger kan forstyrre hjortevilt som følge av koronastøy og elektromagnetiske felt. Resultatene viser at elg ikke unngår kraftledningsgater, men tvert om ofte benytter dem som beiteområder. Elger ser ut til å bruke mye tid i kraftledningsgaten og andre økotoner i studieområdet,

trolig på grunn av god næringstilgang og bedre skjul sammenlignet med åpne områder. Elg ser imidlertid ut til å unngå veier, spesielt når de går parallelt med elver.

Skogslevende hjortedyr kan gjøre seg nytte av beitemulighetene i ryddebeltene i tilknytning til kraftledninger hvis disse pleies slik at de representerer en næringsressurs, samt gir skjul. Størst fordel kan forventes når kraftledninger går gjennom gammel barskog som i seg selv tilbyr dårlig beite. Selektiv hogst av tre som når opp i omkring fem meter sikrer kontinuerlig mattilgang samtidig som de skjul. Alternativt kan løvtrærne kuttes til ca. en meters høyde eller halvfelles (dvs. skjæres over slik at de kan veltes, men fremdeles holder seg i live – «hinge-cutting») i stedet for total rydding. Dette vil korte ned perioden med dårlig næringstilgang etter at kraftledningsgata ble ryddet. Kraftledningsgater kan lette tilgangen til jaktområder for jegere, så vel som for rovdyr. Bygging av kraftledninger bør unngås i kalvingsperiodene til hjortevilt for å unngå negativ innvirkning på reproduksjonen.

Det er behov for mer forskning for å finne ut unnvikelses og barriereeffekten til kraftledninger øker når de ligger i tilknytning til annen infrastruktur, og hvilken innflytelse ryddebeltets bredde har i forhold til kyssingsvillighet og kanteffekt. For å finne mer ut om årsakssammenhengen mellom etablering av kraftledninger og mulig unnvikelse, bør det foretas før- og etterundersøkelser kombinert med registrering av andre forstyrrelsesfaktorer og næringstilgang.

WP2. Linjetakseringer og DNA-analyser har gitt data omkring bestandsstørrelse for orrfugl og storfugl i perioden mars-april. Regulære søk med en trenet hund er utført for å finne kollisjonsdrepte fugler i kraftledningens ryddebelte. I 2011 ble bestanden i undersøkelsesområdet estimert til å bestå av 86 orrfugl (3,0 individer/km^2) og 34 storfugl (1,2 fugler/km^2). 29 steder med kollisjonsdrepte fugler/rester etter fugler, ble identifisert. DNA-analyser ble brukt til å identifisere 19 ulike individer fra 5 arter blant kollisjonsofrene, bl.a. 4 storfugl og 4 orrfugl. I 2012 ble i alt 29 forskjellige orrfugl og 23 storfugl identifisert på bakgrunn av DNA analyser. Bestanden i studieområdet ble estimert til 70 storfugl (2,4 fugler pr km2) og 56 storfugl (1,9 fugler/km2). 20 steder med kollisjonsdrepte fugler ble funnet. DNA-analyser ble brukt til å identifisere 14 forskjellige individer fra 9 arter blant kollisjonsofrene, bl.a. 3 storfugl og 1 orrfugl. I 2013 ble det i alt identifisert 15 forskjellige individer av storfugl og 63 av orrfugl på bakgrunn av DNA-analyser av ekskrementer. Bestanden i området ble estimert til å bestå av 99 orrfugl (3,4 fugler/km2) og 24 storfugl (0,8 fugler/km2). Pr. oktober 2013 var det blitt gjennomført 12 søk etter døde fugler dette 3. studieåret, og 19 steder med kollisjonsdrepte fugler/rester etter fugler var funnet. På bakgrunn av DNA-analyser ble 13 forskjellige individer fra 8 arter identifisert, blant annet 1 storfugl og 7 orrfugl. Våren 2014 gjorde værforholdene videre innsamling av ekskrementer for DNA-analyse umulig. I løpet av slutten av april 2014 ble spill-/leikplasser langs det undersøkte kraftledningsavsnittet registrert, og 5 spillplasser for orrfugl ble funnet. Et siste søk etter kollisjonsdrepte fugler vil bli utført i uke 21. De siste DNA-analysene vil bli utført til høsten.

DNA-analyser basert på ekskrement-innsamling synes å gi pålitelige bestandsestimater for storfugl og orrfugl, til en forholdsvis lav tidsmessig sog økonomisk kostnad. Metoden reduserer også mulighetene for å overestimere bestandsstørrelsen og antall kollisjonsoffer. Det er flere feilkilder knyttet til innsamling av kollisjonsdrepte fugler i kraftledningskorridorer, og noen ganger kan det være vanskelig å avgjøre hvorvidt atskilte fjærrester og rester etter fugler stammer fra samme ulykke. Gjennom å bruke DNA-analyser er denne feilkilden eliminert. Den foreløpige konklusjonen er at kollisjonsdødelighet mot kraftledninger reduserer bestand av storfugl og orrfugl i perioden 2011-2013 med henholdsvis 4,2-11,8 % og 1,4-8,1 %. En slik tilleggs-dødeligheten bør tas i betraktning når f.eks. jaktuttaket i området skal fastsettes.

WP3. På grunn av begrensninger i forhold til analyse kapasiteten innenfor GIS i NINA, er prosjektet forsinket, og resultatene vil bli presentert på et senere tidspunkt.

En funksjonell prototype av database ble ferdigstilt allerede i 2009. Imidlertid ble det bestemt at en også skulle undersøke mulighetene for å samarbeide med Artsdatabanken, som på dette tidspunktet nettopp hadde utviklet en egen portal for innrapportering av arter på nett – www.arts-observasjoner.no. Dette ble raskt et populært nettsted hvor folk daglig bidro med flere hundre fugleobservasjoner. Gjennom en del modifiseringer og forslag fra NINA, ble nettstedet etter hvert tilrettelagt for innrapportering av funn av døde fugler. Antall innrapporteringer av døde fugler der dødsårsaken skyldes kraftledninger har vært forholdsvis lav og stabil de tre årene basen har vært tilgjengelig (25 både i 2011 og 2012, 33 i 2013).

WP5. LCP metoden kan være et nyttig planleggingsverktøy i en tidlig fase av en utbygging for å gi oversikt i forhold til konsekvensutredningsbehov, redusere potensielle konflikter mellom interessegrupper og gjøre prosessen mer transparent for allmennheten. I forhold til prosjekteringssyklusen for kraftledningsutbygging vurderer Statnett OPTIPOL-LCP å kunne være et nyttig verktøy i tilknytning til innledende egnethetsvurderinger og den offentlige høringsfasen før det offisielle konsekvensutredningsprogrammet fastsettes.

OPTIPOL-LCP har vært presentert på flere internasjonale konferanser der konsekvensutredninger, sosiale virkinger av et godt miljø, kraftledningskorridorer og kartteknologi og GIS har vært tema. Tilbakemeldinger fra bl.a. EU kommisjonen (DGE Environment) har spesielt understreket potensialet til OPTIPOL-LCP, bl.a. som et verktøy i tilknytning til holistiske beslutningsprosesser, demokratisering, brukermedvirkning og økt effektivitet i tilknytning til store utviklingsprosesser. Også STATOIL har uttrykt interesse for OPTIPOL-LCP som verktøy, bl.a. i tilknytning til trasevalg for offshore rørledninger. EISCAT (European Incoherent SCATter – http://www.eiscat.se/) er også interessert i å vurdere bruk av verktøyet ved etablering av sine radaranlegg på samme måte som Fylkesmannen i Sør-Trøndelag i forhold til plassering av vindkraftverk.

LCP-metoden vil bli videreutviklet og tilpasset «least cost siting» (LCS) innenfor budsjettet til CEDRENs generelle aktiviteter i perioden 2014-2016. NINA og flere internasjonale partnere har også inkludert OPTIPOL-LCP i ulike prosjektsøknader med fokus på oppdrettsanlegg for fisk (Horizon 2020) og plassering av vindkraftverk (European Economic Area Grants for Tsjekkia, Romania og Litauen).

OPTIPOL-LCO 2.0. er på nåværende tidspunkt bare operasjonell som desktop-plattform, og er følgelig lite tilgjengelig for bruk av flere samtidig, f.eks. på meldingsfasen av et kraftledningsprosjekt. OPTIPOL-LCO 2.0. er basert på ESRI-teknologi og direkte kompatibel med ESRI ArcGIS sin server-plattform. For å videreutvikle og teste metoden, verktøyet og bruken av kriteriene, er det viktig å etablere samarbeid med en partner. Prosjektsamarbeidet bør fokusere på teknologi og metodeutvikling og prosesser knyttet til økt brukermedvirkning.

WP6/WP8. Denne revystudien har gjennomgått tilgjengelig litteratur omkring fuglers syn for bedre å kunne forstå hvordan ulike typer kamuflering av kraftledninger kan påvirke kollisjonsfaren for fugl og hvordan ulike typer overflatebehandling av faseledere og metall kan påvirke tekniske aspekter i forhold til eksempelvis korrosjon.

Øyet hos pattedyr og fugler har mange fellestrekk, og anatomi og funksjon er forholdsvis godt studert og forstått, og det viser seg at det ikke er korrekt å anta at måten ulike arter ser omgivelsene på er lik. Når det gjelder fugleøyets fargesyn, dybdesyn og synsskarphet, er det mange ubesvarte spørsmål i forhold til fargekamuflering av kraftledninger. For å oppnå en optimal deteksjon av en kraftledning for fugl er det viktig å optimalisere linenes kontrastvirkning i forhold til fargene i bakgrunnen. Flere forskere mener enkelte fuglearter har en betydelig evne til å skille farger i den gule delen av spekteret, og det synes sannsynlig at enkelte grønne og gule farger, særlig hvis de samtidig har et UV-bidrag, gir kontrast mot en naturlig grønn bakgrunn. Å minske kontrastvirkningen mellom en luftline og linens bakgrunn – f.eks. gjennom å matte ned den blanke overflaten på en FeAl-line med sort eller gråsort farge – vil trolig øke kollisjonsrisikoen for en del fuglearter. For å gjøre faseledere og jordliner så synlige som mulig, er det fra et ”fugleperspektiv” sannsynligvis generelt gunstigst å lokalisere kraftledninger slik at de skaper kontraster i forhold til en bakgrunn. Årstidsvariasjonene i Norge gjør at de fleste naturtyper gjennomgår en "fargesyklus" - fra hvitt om vinteren via brunt/svart om våren til grønt om sommeren og gult/rødt om høsten. I perioder av året vil derfor - uansett hvilken kamuflasjefarge som benyttes – en kraftledning være mer synlig enn til andre årstider.

I eksponerte kystområder er det stor sannsynlighet for spaltekorrosjon under belegg med dårlig heft. Belegg som påføres etter at linetrådene er slått, har en tendens til å hindre drenasje i linen. Belegget fremmer dermed innvendig korrosjon mellom trådene og trådlagene og spesielt i linens laveste punkt. Mattede eller primede kamuflasjeliner synes å klare seg godt i kystmiljø med lav korrosivitet. Emisjonsfaktoren ε er avhengig av linens overflatebeskaffenhet. Ved å øke linens emisjonsfaktor kan kjølingen økes pga. utstrålt varme slik at det oppnås en økning i den strømførende kapasiteten på ca. 5 %. Isolerende belegg på kamuflasjelinen kan føre til kontaktproblemer og havari, og skal derfor tas hensyn til ved montasje og valg av kontaktforbindelser. Før montasje av klemmer og skjøter, må kontaktflatene behandles med stålbørste, smergelduk o.l. umiddelbart før montasje. I tillegg bør kontaktflatene påføres et tynt lag med fett som hemmer oksidvekst, og forsegler kontaktområdene mot inntrengning av vann og forurensning, som kan føre til korrosjon

WP7/WP8. Denne revystudien har gjennomgått tilgjengelig litteratur omkring tiltak som kan redusere omfanget av fuglekollisjoner med kraftledninger og elektrokusjon, og hvordan ulike typer tiltak kan påvirke sikkerheten i strømleveranse.

Både kollisjoner med kraftledninger og elektrokusjon er sterkt arts-, steds- og årstidsspesifikke ulykker. Det er derfor viktig at fremtidig forskning blir mer steds- og artsspesifikk i tilnærmingen til problemløsninger, og at tiltakene mer faktabaserte: 1) Hvilke arter er mest utsatt (målarten(e); 2) hva er beste design av merking i forhold til å redusere kollisjonsrisiko hos målarten(e); 3) hva er suksessraten eller sannsynligheten for å redusere dødelighet basert på den økonomiske investering knyttet til merking av kraftledninger. Gjennom slik kunnskap blir det enklere å argumentere for nytteverdien til avhjelpende tiltak, det være seg miljømessig eller monetært. Kunnskap om bestandsmessige konsekvenser av ekstra dødelighet hos fugl som skyldes kollisjon og elektrokusjon er så godt som fraværende, og vil være et særlig viktig fokusområde for fremtidig forskning.

Fysisk forstørrelse av fase- og/eller jordline gjennom en eller annen form for kjent merkemetodikk, har for enkelte arter ført til redusert kollisjonshyppighet. Generell merking ved nybygging av kraftledninger kan forsvares i områder der det er kjente kollisjonspunkter («hot spots»), mye fugl (eksempelvis våtmarksområder), ved kryssing av opplagte ledelinjer (f.eks. elver, trange daler og sund), når linene krysser lokale trekkveier mellom funksjon- og ressursområder (f.eks. hekkeplass og næringsområde), og der det oppholder seg mange dagaktive arter og arter kjent for å kollidere (f.eks. svaner og traner).

For å øke kunnskapen om når og hvor det bør merkes, er det behov for mer data om arts- og stedsspesifikk kollisjonsrisiko og artsspesifikke atferdsresponser i forhold til ulike merkingstyper. For enkelte arter vil det trolig ikke finnes gode løsninger («no cure species») bortsett fra jordkabling. Lang skumringsperiode og svært kort daglengde, slik som i Nord-Europa og Norge gjennom vinterhalvåret (nær seks måneder), gir små muligheter for å redusere dødelighet hos eksempelvis hønsefugl, som er dokumentert å være spesielt utsatt for kollisjonsulykker.

Foreliggende rapport fokuserer eksisterende nett, og tiltak som går på hvor ledningen bør plasseres i terrenget og andre forhold som bare kan tillegges vekt ved nybygging, er derfor ikke behandlet. Det er imidlertid liten tvil om at de beste forebyggende tiltak mot fuglekollisjoner oppnås gjennom et godt trasevalg.

Elektrokusjonsfare hos fugl er primært knyttet til kraftforsyningsstrukturer i nettsystemer fra 66 kV og nedover, og kunnskapen om hvilke tekniske konstruksjoner som fører til elektrokusjonsulykker er betydelig. Dessverre er anbefalinger gitt allerede for 25 år siden ikke fulgt opp, og mye av årsaken til elektrokusjonsdødelighet hos fugl i Norge skyldes at eksisterende informasjon og løsninger ikke er implementert.

Mange nettselskaper opplever hyppige driftsforstyrrelser på grunn av elektrokusjonsulykker med fugl. Årsstatistikken over hendelser, driftsforstyrrelser og feil i 1-22 kV-nettet for 2008 viser at fugler/dyr utgjør ca.13 % av alle driftsforstyrrelser og 3 % av ikke levert energi. Midlere antall driftsforstyrrelser på grunn av fugler/dyr er trolig 8-10 ganger høyere på kysten enn i innlandsområder, men med store lokale variasjoner innenfor forsyningsområdene på kysten. Også fra nettselskapenes ståsted er det derfor viktig at det kan settes i verk tiltak som reduserer driftsforstyrrelser som skyldes fugl. Det er imidlertid viktig at alle tiltak som settes i verk for å redusere omfang av kollisjoner/elektrokusjon av fugl ikke kommer i konflikt med driftssikkerheten i strømforsyningssystemene.

Ved å isolere traverser av metall unngås elektriske sjokk og jordfeilstrømmer fra faseleder til jord når fugl setter seg i stolpen. Dette kan redusere antall kortvarige avbrudd i nett uten spolejordet nullpunkt. Ulempen er økt sannsynlighet for korrosjon og manglende utkobling hvis fasen ramler ned på traversen. Montering av fuglevern på gnisthornet kan også redusere antall kortvarige avbrudd i nettet som følge av jordfeilstrømmer.

WP9. Data fra GPS-satellitt senderne har gitt ny kunnskap om hvordan hubro benytter kraftledningsstolper innenfor sine leveområder og under næringssøk. Også bruk har viltkamera og direkte observasjoner har gitt interessant informasjon om dette. I et åpent kystlandskap som Solværøyene, blir kraftledningsstoler ofte benyttet av hubro under næringssøk. Telemetristudien har også gitt ny informasjon om størrelsen til hjemmeområdet hos voksne hubro og spredningsmønsteret hos ungfugl.

DNA-analyser fra hubrofjær samlet fra reirplasser har vært vellykket, men det er så langt for lite materiale fra de samme territoriene over flere år for å estimere dødelighetsraten hos voksne fugler. Det er derfor viktig at prosjektet videreføres. DNA-analyser vil også være et viktig hjelpemiddel for å identifisere ulike reir i forhold til territorier. Dette er viktig for å kunne få et bedre estimat for bestandsstørrelsen av hubro i Solværøyene, som har en meget tett hekkebestand.

Søket etter døde hubro og andre fugler under kraftledningene og stolpene har gitt verdifull informasjon om hvilke strukturer som er de farligste i forhold til elektrokusjon, en kunnskap som er viktig for effektive tiltak og en kostnadseffektiv oppfølging av handlingsplanen for hubro.

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Preface

In early 2008 the Norwegian Parliament (Stortinget), adopted a national R&D strategy *Energi21,* and decided to earmark at least NOK 100 million per year to «Centres for Environment-friendly Energy Research» (CEER). The money was allocated to the Research Council of Norway (NFR) to grant eight CEERs, based on applications from Norwegian research institutions. The application process was initiated in May 2008 and the Research Council Executive Board took a final decision on the winners on January 28 2009. The official announcement was made by the Minister of Oil and Energy February 4 2009.

One of the applications was designed by a consortium with he Foundation for Scientific and Industrial Research (SINTEF), the Norwegian University of Science and Technology (NTNU) and the Norwegian Institute for Nature Research (NINA). The application focus was on future development of renewable energy (hydro- and wind-power) and the power-line grid system, with an overall objective 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 application was successful and the *Centre for environmental design of renewable energy* (CEDREN) became a reality. The design of the CEDREN application was mainly based on running projects among the three institutions in the consortium, or applications recently sent to NFR. One of these was OPTIPOL - «*Optimal design and routing of power lines; ecological, technical and economic perspectives*».

OPTIPOL was designed by NINA in early 2008, with a particular focus on power lines and wildlife interactions. Shortly before CEDREN became operative, NINA was informed by NFR that OPTIPOL was granted with approximately NOK 17 million over a five year period (2009-2013). As soon as CEDREN was approved as a CEER, OPTIPOL became an integrated part of the centre. The comprehensive and challenging goal framework of OPTIPOL, economically as well as scientifically, had to be carried out within a team of scientific experts with ecological, social as well as technological background. Thus the project fitted well into the CEDREN construction. Apart from NFR, Statkraft, Statnett, the Norwegian Water Resources and Energy Directorate (NVE), the Norwegian Environment Agency, the Norwegian Electricity Industry Association (Energy Norway) and several other partners, economically supported by CEDREN.

Trondheim, ultimo January 2014

Kjetil Bevanger
Project leader

1 Introduction

«*Environmental concern in right-of-way management*» has been a focal research area for many years, particularly in North America, and the topic is devoted an international symposium series (http://rights-of-way.org/). The first symposium was held at Mississippi State University in 1976, and the tenth in Phoenix Arizona 2012. These symposia have addressed a range of environmental issues in rights-of-way (ROW) planning and management, and been an important forum for information exchange among environmental professionals from the energy industries, academic organizations and others. The symposium proceedings is a valuable source of information to those interested in ROW issues.

With an overhead power-line grid close to 200 000 km (http://www.ssb.no/elektrisitetaar/tab-2009-05-28-08.html), the associated ROWs affect a significant part of the land area in Norway tying up between 1500 and 2000 km^2 (Bevanger 2011). Focus on environmental and management issues connected to power lines (and other ROWs) has not been an issue of particular priority among environmental and energy management authorities in Norway. Landowners with their properties criss-crossed by power lines look at these corridors as «wasteland» as well.

January 1 1984, the ØKOFORSK Research Programme, financed by the Research Council of Norway, was launched. Research on interactions between the power-line grid and birds became an important part of the ØKOFORSK activities at the unit located at the Natural History Museum, University of Trondheim, right from the beginning (Bevanger 1984, 1987, 1988 a, b, c, Bevanger & Thingstad 1988). In September 1988 ØKOFORSK was merged with the research divisions at the Norwegian Directorate for Nature Management to the Norwegian Institute for Nature Research (NINA), and the research activities on birds and power lines continued within NINA, and has also been a regular issue addressed in connection to EIAs (May et al. 2012).

The fact that birds are killed by flying into power lines has more or less made this the focal point of research when it comes to environmental impacts of utility structures. In the same way as power lines ties up vast land areas, the bird mortality reflect both an ecological and economic problem. Birds being electrocuted frequently cause power outages and thus have an economic impact (Bevanger & Refsnæs 2013a). 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.

Power lines also impact mammals. To maintain viable populations of the European wild reindeer is an important task for Norway, being the last stronghold for the species. Thus, the question on how power lines may affect reindeer has been on the agenda several times, although the knowledge on this was very scanty until 1996 when Statnett initiated discussions on how to improve the situation. After a workshop arranged by Statnett in early 1997, it was decided to make a pilot study (May et al. 2012). The study concluded that it had been more or less a standstill in the knowledge gain on the topic since the last review in the mid 1980ies. It was also underscored to give priority to some specific topics in future research activities. In spring 1998 Statnett initiated the so called REIN Project, as part of the EFFEKT Programme within the Research Council of Norway. The main scientific contributions came from the University of Oslo (UiO), NINA and the Norwegian University of Life Sciences (UMB) (Flydal et al. 2002).

The REIN Project made several interesting findings regarding power-line impact on reindeer. It turned out that corona discharge noise from the power lines is audible for reindeer, but not necessarily disturbing, and that direct exposure to power-line constructions has a limited impact on the local behaviour of the reindeer. Moreover, it was evident that the construction phase has the strongest, short term disturbing impact, but limited long-term effect (Flydal et al. 2002). One the other hand it turned out that reindeer avoided power lines, reducing the area use up to several kilometres from the power-line corridor. It was also evident that females with calves were most vulnerable to these disturbances, though there were seasonal differences in the disturbance effect. In short, the REIN Project raised many new questions still pending. The debate on local scaring impacts or regional avoidance effects with respect to reindeer is e.g. still going on, and research on human induced disturbance impacts on reindeer has become a main focus for researchers in NINA (e.g. Strand et al. 2011; Panzacchi et al. 2011) and the University of Oslo (e.g. Reimers et al. 2007; Flydal et al. 2009).

During the design of OPTIPOL, the knowledge from previous research on environmental impacts from power lines were considered carefully, and one of the obvious areas of knowledge gaps was how transmission lines could affect ungulates – in general. A related issue was linked to how «wasteland» areas connected to the power-line corridors possibly could be improved; 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.

Regarding avian questions, the knowledge is considerable when it comes to what species being the most vulnerable, where and when (Bevanger 1994a, b, 1998). The knowledge gap is connected to the population impact and collision hot spots. Moreover, due to a particular interest from the energy management authorities on bird electrocution and collision mitigating measures, as well as power-line camouflaging, these issues were prioritized in the new project. How to deal with the electrocution problem connected to a red-listed species like the eagle owl also became a specific task. Finally, and the overall question was – is it possible to improve the planning process for an optimal routing of a power line using advanced GIS technology?

Besides the recognition of these knowledge gaps, the OPTIPOL rationale is based on the belief that the negative impacts to wildlife of electricity transmission and distribution still have a potential to be reduced. However, to develop effective mitigating measures, e.g. to reduce the number of birds being electrocuted 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 construction design within the Norwegian grid system must be considered carefully when it comes to retrofitting actions in order to safeguard the stability of energy supply to the consumer as well as not violate safety regulations. The CEDREN consortium and the associated scientists cover most of the applied ecological challenges faced connected to the identified questions and made a unique opportunity to take the understanding of these complex issues a step forward.

To achieve European-level policy goals on climate change challenges, as well as securing the electricity supply within Norway, it will be necessary to increase power-line construction and retrofitting efforts significantly. To upgrade the existing central grid for future needs Statnett have estimated an approximately 40-50 billion NOK investment over the next 10-20 years. Thus, the overall objectives of OPTIPOL are to contribute to an environmental friendly future development of the grid by developing predicting tools for optimal routing of power lines, and assess technical and economic solutions to minimize conflicts with wildlife and habitat conservation. Rights-of-way (ROW) and power-line (clear felled) corridor is used as synonym expressions throughout the report.

To achieve this goal the work was subdivided into focal areas and work packages:

- **WP1. Power line ROW as habitat resources for moose (*Alces alces*) and other wildlife,** with an objective to assess how and why different wildlife species use deforested areas below power lines and evaluate possible positive and negative effects of power line ROW´s. The target species has been moose. The specific objectives have been to
-
    - assess habitat use of power-line ROWs by different wildlife species
    - examine if power-line ROWs represent suitable feeding grounds for moose
    - investigate the influence of power lines on moose habitat selection

  - find out if moose avoid crossing power lines, or if moose use these structures as movement corridors
  - find ways of improving power-line ROWs as wildlife habitats
  - evaluate possible positive and negative effects of power-line ROWs on wildlife

- **WP2. Capercaillie (*Tetrao urogallus*) and black grouse (*Tetrao tetrix*) population responses to power-line induced mortality,** with an objective to assess population impact of bird mortality due to collisions with power lines, relative to other human-related mortality factors (primarily hunting) in gallinaceous birds (with capercaillie and black grouse as model species).

- **WP3. Bird collision hot spots,** with an objective to 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

  - a trained dog for data sampling
  - existing dataset from earlier projects on birds and power lines
  - a national dead-bird database
  - advanced statistical/GIS-modelling

- **WP4. National database for reporting on dead birds**, with an objective to develop and implement a SQL-server spatial database for storing and retrieval of dead-bird data.

- **WP5. A Least Cost Path (LCP) toolbox for optimal routing of power lines**, with an objective to develop a LCP-desktop GIS toolbox for optimal routing of transmission lines based on ecological, economic and technological criteria.

- **WP6. Power-line camouflaging**, with an objective to assess, based on available literature, the possibilities for increased collision hazard to birds by making the power line structures less visible to humans.

- **WP7. Mitigating effect of power-line marking and modifications**, with an objective to review available literature on technical modifying solutions and assess their effectiveness to mitigate bird collisions and electrocution.

- **WP8. Guidelines for technical solutions to mitigate power-line induced mortality to birds**, with an objective to

  - 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

WP6, 7 and 8 is closely connected, and has been reported in two separate reports (see Bevanger & Refsnæs 2013 a, b and references therein).

- **WP9. Eagle owl (*Bubo bubo*) population impact of power-line induced mortality**, with an objective to assess eagle owl mortality and population impact due to utility structures, identify high-hazard electrocution structures, and test effectiveness of design modifications of these.

The project activities have been reported through annual reports (Bevanger et al. 2009, 2010, 2011, 2012), as well as in scientific journals and conference proceeding. The content in the present report is restricted to give an overview of the work package activities and summarizes their findings. The project was formally finalized at the end of 2013, however, some activities in WP2 and WP3 have been delayed and will be reported in separate publications. WP9 will continue as a NINA project if it is possible to find money.

OPTIPOL has been a project focusing applied research topics, and several user groups (energy industry, environmental and energy management authorities) have been closely involved during the project period, both formally and informally. Five annual meetings have been arranged; the first in early 2009, and the last in early February 2014. In general, the annual meeting have focused on achievements and progress within the project work packages, followed by discussions and input from the participants. In the last meeting, February 4 2014, which also represented the formal termination of the project, a significant part of the time was used to discuss future research needs in connection to utility structures. Thus, an important aim of the meeting was to improve our understanding on how the users groups assessed the knowledge gaps and upcoming challenges. For summary of the discussion see **Appendix 1.**

2 Power line ROW as habitat resources for moose and other wildlife

2.1 Background

Transmission lines with voltage up to 420 kV have an associated security area creating a clear-felled corridor in forest landscapes width a total with of approximately 40 m (i.e. 20 m on each side of the centreline of the power line). They may be considered as a source of loss and fragmentation of wildlife habitat. The physical structure and noise emitted by power lines could result in avoidance by e.g. reindeer (Nellemann et al. 2001, Vistnes et al. 2001, Nellemann et al. 2003) and barrier effects (Vistnes et al. 2004). However, power-line ROW have the potential to provide a stable source of additional browsing resources for moose (Ricard & Doucet 1999), since they are routinely cleared of trees for security reasons. Although moose avoid open habitat types providing little food and cover, they increase the selection of open habitat types when these provide abundant forage (Bjørneraas et al. 2011). When foraging opportunities as well as cover are close to the power-line ROW forest edges, these areas could be particularly attractive to moose. The moose was selected as a model species because of its known preferences for habitats providing food and cover, as well as its importance to hunting and forestry (Storaas et al. 2001).

2.2 Research area

To optimize resource use it was decided that WP1 (*Power line ROW as habitat resources for moose*) and WP2 (*Capercaillie and black grouse population responses to power-line induced mortality*) should use the same area during the fieldwork activities. The study area selection process was not finalised until late autumn 2009 (Bevanger et al. 2009), and a six km section of a 300 kV transmission line in Bangdalen (Namsos local authority) was chosen (**Figure 1**). One main reason for choosing this area was the concentration of moose during wintertime and a developed system of forest roads partly paralleling the power line, making access easier. However, when the WP2 fieldwork started in March 2010, low capercaillie and black grouse densities, together with a very rough terrain consuming too much of the available resources, made it necessary to move WP to another area (Ogndalen**; Figure 1**). Whereas WP1 continued working in Bangdalen due to good opportunities for collecting data of moose movement and browsing.

The dominant habitat type in Bangdalen is spruce forest of intermediate and low productivity interspersed with mire. The elevation ranges from 138 to 409 meters with an average of 221 (± 61 SD) meters. Parts of the terrain is very rugged. The size of the study area was 6 km^2. A wide-ranging system of forest roads exists in Bangdalen whereof 8.6 km intersected the study area. It is also traversed by a river covering a length of 1.1 km in the study area (**Figure 2**). Moose density estimates were 1.02 and 1.55 individuals per square km forest in the northern and southern part of the study area, which was divided between two communities. These moose densities lie above the average of one moose per square km in Norway (Solberg et al. 2012).

Figure 1. *Study areas selected for fieldwork, WP1 and WP2, in Bangdalen and Ogndalen.*

2.3 Power line rights-of-way as browsing habitat

2.3.1 Edge effects at a high-voltage power line on moose browsing habitat

Forest edges created by a power line clear-felled corridor, could be attractive to moose because they may provide browsing opportunities and protective cover in adjacent forest. We surveyed 528 plots (4 m diameter) distributed randomly within a confined area alongside a power line in the study area in Bangdalen (**Figure 2**). The plots were visited only once. In each plot moose browsing was recorded on birch (*Betula pubescens*) as the number of shoots removed relative to the amount of shoots available. All moose pellet groups inside the plots were counted. A pellet group is defines as a coherent unit of pellets clearly separated from scattered pellets. Plots were surveyed during spring and summer in 2010 and 2011. We expected that browse availability, moose habitat use and browsing intensity should increase in the proximity to power line ROW and other types of forest edges. We analysed the effects of distance forest edge and other covariates on the response variables with zero inflated and generalized linear mixed models and applied model averaging following an information theoretic approach.

The abundance of the main browse species (birch) did not peak at the edge as expected but at approximately 100 m distance from forest edges, possibly because of the interspersion of forests with open habitats around this distance (**Figure 3**). However, the count of shoots on birch trial stems increased from forest interior towards open areas presumably because of the increasing availability of light. Power line ROW provided more birch stems compared to other open areas but fewer stems than forests. Habitat use did not peak at the edge as we expected but in forests at 50 m distance from edge possibly because of better canopy cover. During the year preceding the study moose browsed a higher proportion of available shoots in open areas close to power line ROW edges compared to other open areas, possibly because of increased forage availability and better cover in adjacent forest. Browsing intensity during the previous years corresponded to the peak in availability of birch stems in forests at 100 m distance from an edge. The results indicate that moose in the study area mostly use forests between 50 and 100 m from power line ROW and other forest edges. It appears that moose were tolerant to the presence of the power line.

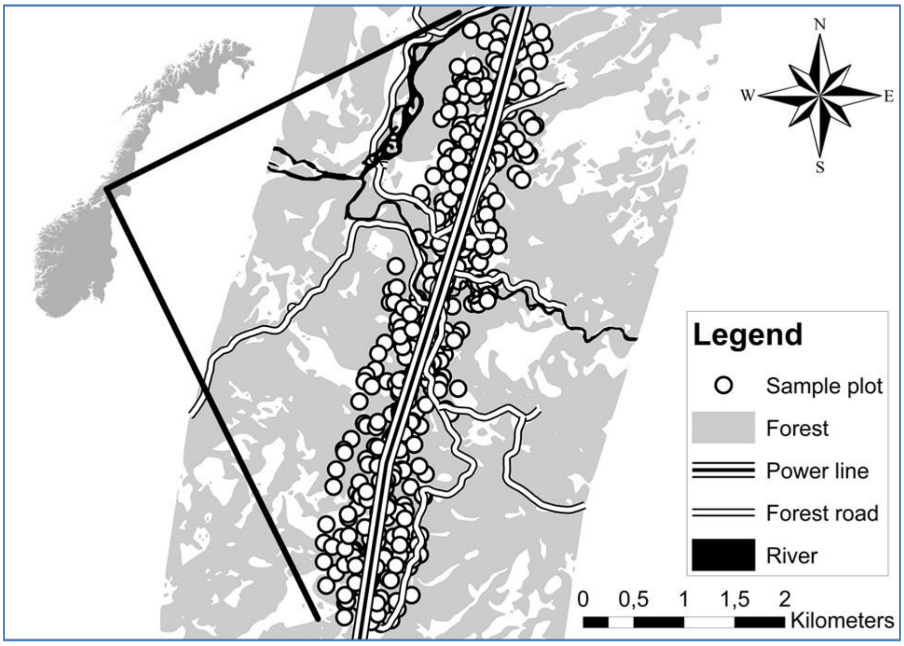


Figure 2. *Sample plots (white circles) surveyed for availability of browsing plants, pellet groups and browsing intensity. Areas covered by forest (in grey), forest roads (double line) and a river (black area) are depicted.*

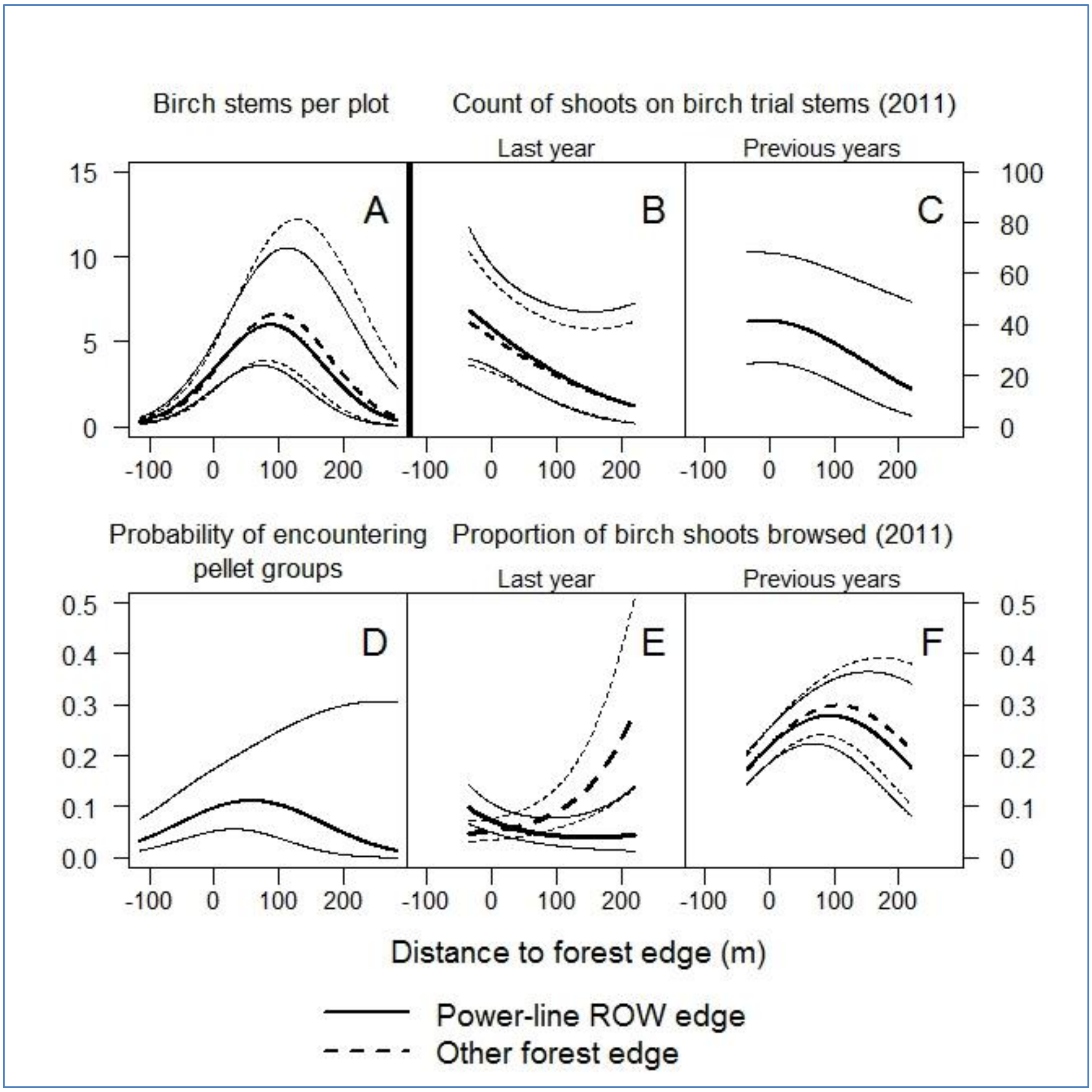


Figure 3. *Availability of browse (birch stems and shoots on stems), probability of encountering moose pellet groups and browsing intensity on birch in survey plots dependent on distance to power line ROW (dashed lines) and other types forest edges (solid lines). Thin lines are model-averaged standard errors of the model-averaged predictions. Distances to forest edges in open habitats are given in negative values. Predictions from analyses using only plots from 2011 are indicated.*

2.3.2 Effects of special pruning regimes on browsing intensity

To assess the possibilities for improving the browsing quality of power-line rights-of-way, it was decided that a 2.5 kilometre section of the power-line corridor should be managed using a special clearing regime (cutting deciduous tree stems around 1 metre above ground) during autumn 2010. The remaining 3.6 kilometres were used as control. Unfortunately, deciduous trees tall enough for pruning occurred only along a 1-kilometre section. To understand how and why moose may use or avoid a power-line corridor, moose feeding intensity and pellet groups were recorded according to the basic method described in 2.2.1, from spring 2010 up to and including spring 2013. In addition, browsing intensity was recorded for all tree species utilised as browse in the area (pine, birch, rowan, alder, juniper, aspen and willow). Both the number of shoots browsed and those not browsed were counted on trial trees in each plot to estimate browsing intensity. This approach allows comparing browsing intensity between the specially cleared areas and conventionally cleared (cutting all trees at ground level) areas as well as before and after clearing. We surveyed 1500 random plots registering 7750 records and 300 moose pellet groups. Only preliminary analyses are available for the time being. It seems that the present finding of moose pellet distribution supports and strengthens the comparative findings (2.3.1), which was based on a shorter time span and thus fewer plots. The distribution of moose pellets in the study area apparently differs from a randomized distribution (**Figure 4**). Most moose pellet groups were found about 100 meters off the power line (**Figure 4**). However, thorough analyses will be implemented shortly and the results are to be presented in reports and scientific journals.

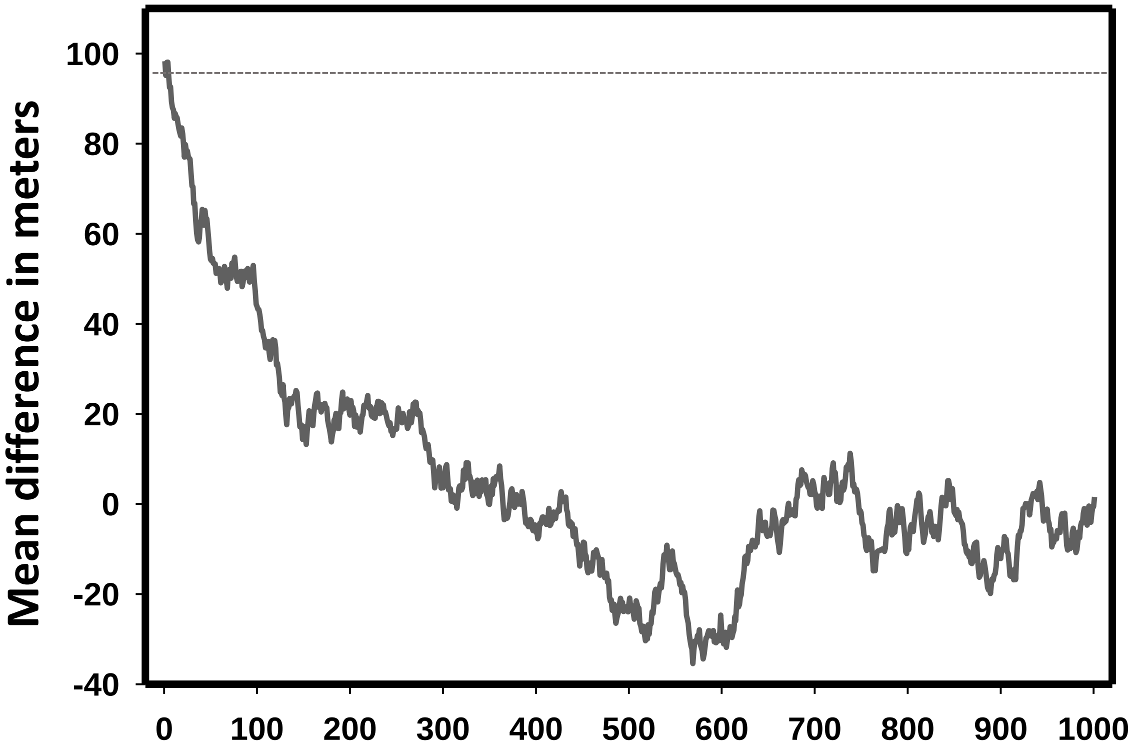


Figure 4. *One thousand generalized Monte Carlo simulations illustrating that the concentration of moose pellet groups, approximately 100 meters off the power line, differs from a random distribution of moose pellets in the same area.*

2.3.3 Wildlife use of ROWs

To increase our knowledge regarding wildlife use of the power line ROW, ten wildlife cameras were applied to record wildlife activity. The cameras recorded continuously during June–December 2010, and gathered information on the presence of animals within and alongside the corridor. The cameras were located inside the different clearing regimes as well as outside the power-line corridor to compare animal visitation rates between the different areas. We relocated the cameras among 25 locations during the study. Information on moose behaviour was obtained through the near video function of the cameras. Although the animals sometimes interacted with the cameras, behavioural activities such as feeding, movement and resting were observed. We have identified 13 different species from photos: badger, fox, hare, moose, pine marten, roe deer, capercaillie, black grouse, crane, fieldfare, crow, song thrush and jay. In addition, domesticated species like sheep were recorded as well as humans. Close to 13000 pictures are analysed and the results will be presented in a report later.

2.4 Moose habitat selection and high-voltage power lines

Several NINA projects focus on different aspects of moose ecology. Collaring animals with satellite radios has been a regular part of the research. Some of these data is made available to the OPTIPOL researchers (**Figur 5**). The numerous fixes may tell, on a larger scale, something about the possible responses of moose to power-line rights-of-way. The analysis of moose GPS-data was initiated by assessing the number of moose positions and turning angles with distance from power lines. Because moose habitat selection is influenced not only by distance to power lines, step selection functions was used to control for the effects of habitat, other types of human infrastructure and further landscape variables.

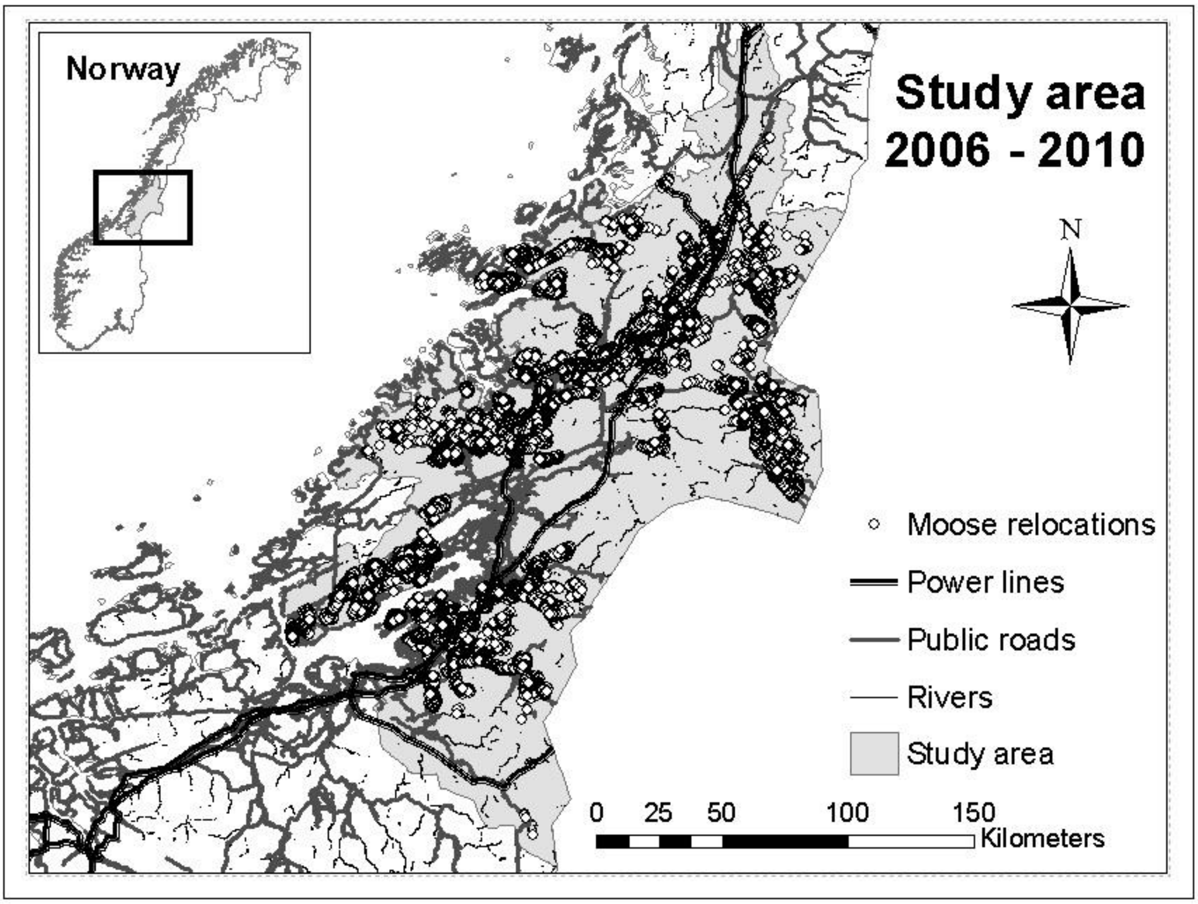


Figure 5. *Study area in Nord-Trøndelag County, central Norway. GPS relocation data (2006-2010) of 151 moose (circles) was used to study corridor and barrier effects of power lines (double line), roads (thick grey lines) and rivers (thin grey lines) as well as linear feature combinations on moose movements.*

2.4.1 Comparative impact of power lines and roads on moose habitat selection

The planned extension of the Central Power-line Grid in Norway is expected to increase loss and fragmentation of wildlife habitat. The public road network is also expanding. However, power line clear-felled corridors and roadside edge vegetation can provide attractive feeding opportunities for moose. While some land owners wish to maintain high moose densities for selling hunting licenses, others are concerned about damage to forest vegetation or the risk of moose-vehicle collisions. The disturbance or attraction potential of power line ROW and roads to moose is therefore of substantial interest. We applied a step selection function on GPS relocation data of 58 moose individuals expecting that central-grid power lines be avoided less than public roads based on their differential disturbance potential (only 58 of the collared moose fulfilled the criteria for analyses – for instance being at least once within a two-kilometer buffer from power lines).

We expected greater avoidance in open habitats because these do not shield from disturbance, less avoidance in winter when moose are in a state of energetic deficit and greater avoidance by female moose. We found no evidence for power line ROW avoidance but moose avoided areas close to roads. However, seasonal and gender-specific differences existed. We did not detect greater avoidance in open habitats. These results will help to develop guidelines for the routing of power lines and roads through different habitat types to minimize disturbance to moose while balancing the interests of landowners and conservationists.

2.4.2 Barrier and corridor effects of linear features on moose movements

Constructing new power lines is required to satisfy increasing demands for energy transmission as well as an improved road network due to an increased population and more cars. Roads and power lines may be movement barriers for ungulates because they could be disturbing and create gaps in the forests. Alternatively, ungulates could use these features as movement corridors because they may be expected to find feeding opportunities in their proximity (**Figure 6**). We compared barrier and corridor effects of roads, power lines and rivers, because they differ in noise levels, visual stimuli and provisioning of feeding opportunities whilst accounting for forest cover and the topographical alignment of linear features. We used GPS relocation data of 151 moose in Central Norway (the Trøndelag Counties), and predicted step selection probabilities for different movement options at varying distances from linear features and linear feature combinations from a step selection function.

Moose did not avoid crossing power lines, unless the placement of power lines along contour lines impeded movements across them. In contrast, moose avoided crossing of roads and rivers in forests (**Figure 7**). Possibly the provisioning of browsing plants increased their willingness to traverse areas cleared of large trees under power lines. Moose more likely moved along linear features when getting closer to linear features. Barrier and corridor effects increased for road/river combinations but the results for combinations of power lines with roads or rivers was inconsistent probably because of the low sample size (**Figure 8**). We found several indications of increased disturbance potential of roads compared to power lines and rivers. This may result in uneven area use and reduced access to seasonal feeding and cover habitats. Power lines could provide most benefits from additional feeding opportunities. Managing vegetation in power-line corridors to provide abundant browse could reduce potential disturbance while wildlife overpasses may be most appropriate to mitigate road fragmentation effects.

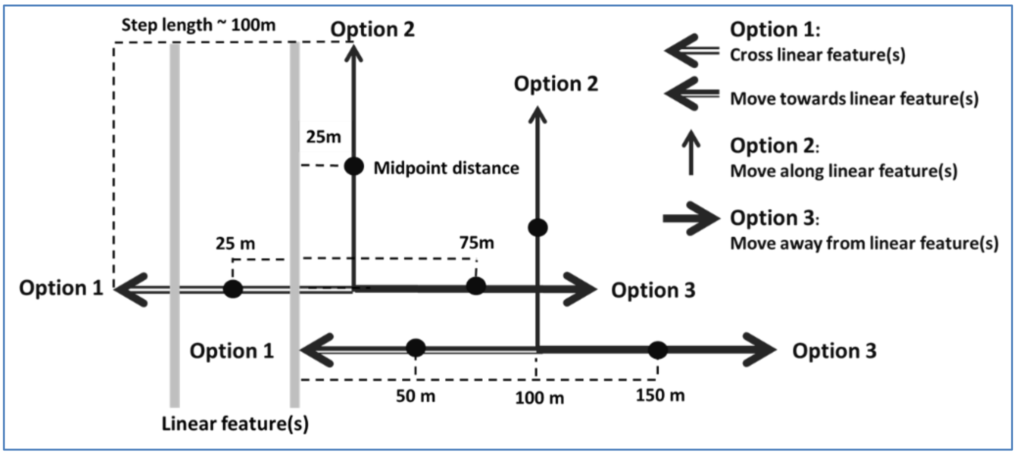


Figure 6. *Moose movement options in response to linear features. The probability of response to crossing linear feature(s): 1) crossing over (upper double line), 2) moving/walking along (thin lines) or 3) moving/walking away from (thick line) were predicted for situations when moose were in close enough proximity to cross (25 m, close to the edge), assuming a step length of 100 m (based on distance between consecutive fixes). At further distances (≥ 100 m) the three possible options were moving towards (lower double line), along (thin lines) or away from (thick lines) linear features without the option to cross linear features.*

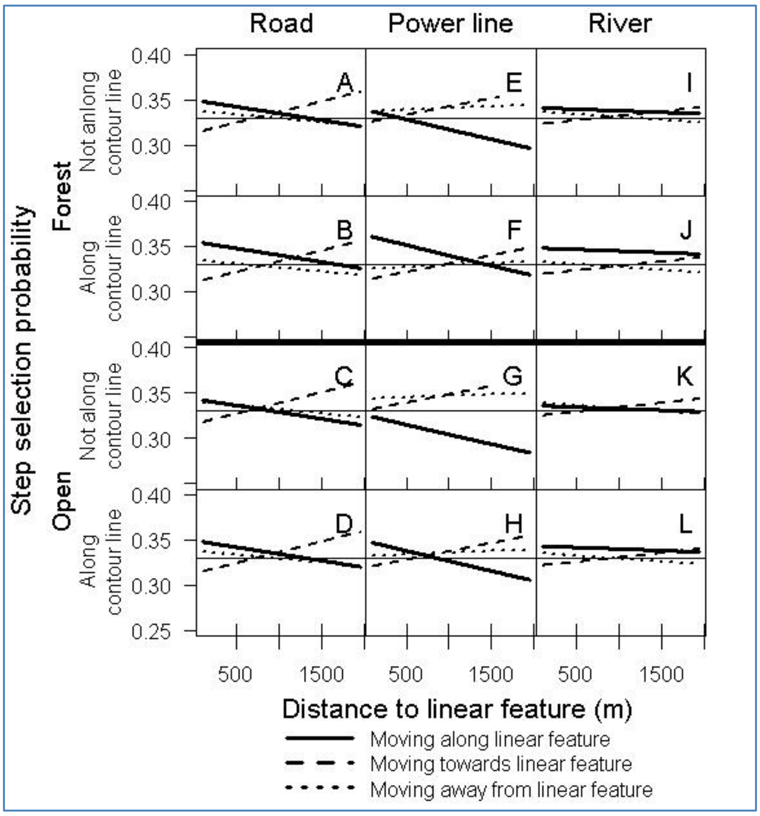


Figure 7. *Step selection probabilities for moose movements along (straight lines), towards (dashed lines) and away (dotted lines) from roads, power lines and rivers in relation to distance to linear features in Central Norway. It was assumed that moose did not have the option to cross linear features at a distance equal to or above 100 m. Predictions were made for movements in forest and open habitats and for situations when linear features were aligned along contour or not. A probability below 0.33 indicates avoidance.*

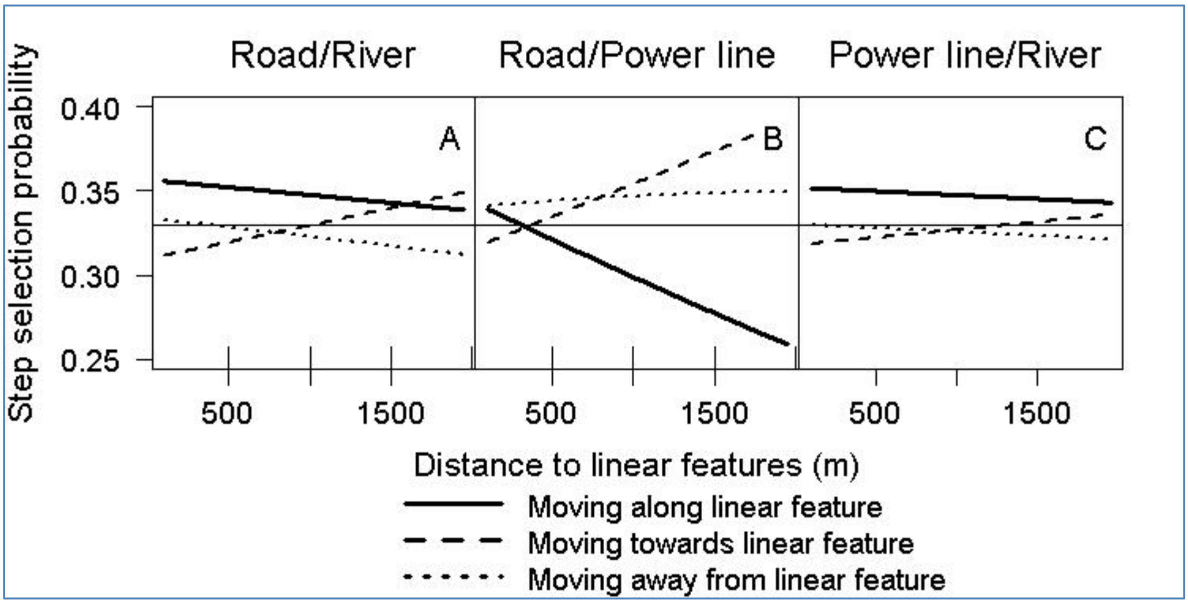


Figure 8. *Step selection probabilities for moose movement steps along (straight lines), towards (dashed lines) and away (dotted lines) from road/river, road/power line and power line/river combinations dependent on distance to the closest linear feature in central-Norway.*

2.5 Conclusions

Power lines could disturb ungulates being artificial structures emitting noise and electromagnetic fields. Mobile ungulates that range over large areas are likely to encounter them. Reindeer (*Rangifer tarandus tarandus*) are suspected to avoid power lines up to distances of 4 km. However, from the reviewed literature we found no evidence that the behaviour of reindeer or forest ungulates is disturbed beneath power lines. Our analyses suggests that moose do not avoid ROWs, and frequently use them for browsing opportunities. Moose seem to use much time alongside ROWs or other edges in the study area, possibly due to forage availability and better cover than in open areas. However, moose seem to avoid roads and especially roads paralleling rivers.

Forest ungulates could benefit from browsing opportunities in the power-line clear felled corridor if they are managed to provide abundant forage and sufficient cover. Most benefits may be expected when power lines are routed through old coniferous forests providing little food. Selectively clearing trees reaching heights of five meters could ensure continuously high browse availability without the removal of cover. Alternatively, cutting deciduous trees at a height of one meter or hinge-cutting instead of full removal could shorten the period of low browse availability after clearing. However, this needs further investigation. Power-line ROW may facilitate access for hunters and provide hunting grounds for predators along forest edges. As a precaution, construction of power lines should be avoided in areas and during times of calving to prevent inference with reproduction.

More research is needed to find out if power lines increase avoidance and barrier effects in relation to other human features and how the width of the clear-felled corridor may influence crossings and edge effects (**Figure 9**). To establish a causal relationship between the construction of power lines and potential avoidance, before-after-impact-control studies are recommended in combination with surveying other disturbance indicators and availability of browse.

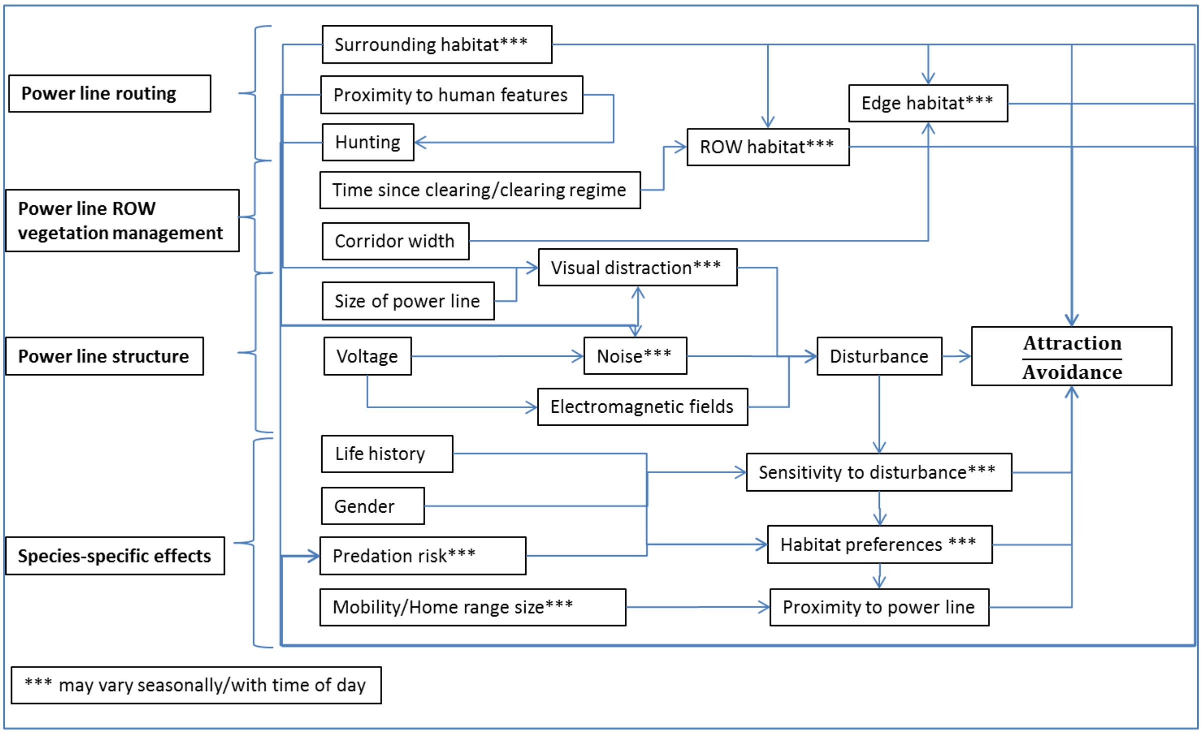


Figure 9. *Possible factors influencing attraction towards or avoidance of power lines by ungulates.*

3 Capercaillie/black grouse population responses to power-line induced mortality

3.1 Background

It is well documented that birds are running the risk of flying into overhead wires with fatal consequences (e.g. Bevanger 1994a, 1998). Some species are, however, more vulnerable to artificial air obstacles than others, and in Norway, gallinaceous birds are among the most frequent collision victims. There are two main concerns connected to this; one is that the Norwegian gallinaceous bird species are popular to small game hunters, particularly during the autumn hunting period. Due to declining population densities, it has become increasingly important to regulate the hunting bag to avoid overexploitation (Pedersen et al. 2004, Sandercock et al. 2011). Willow grouse mortality due to small game hunting may e.g. partly be compensated for compared to natural mortality (hunting mortality are reducing the natural mortality) at a relative low hunting pressure (Pedersen et al. 2004) however, the compensation seems to decrease when the hunting outtake increases (Sandercock et al. 2011).

To advice on a safe hunting outtake, it is important to know the extent of other mortality factors, like collisions with power lines, and how this may influence on the population development. A particular concern is connected to the fact that mortality due to collisions with power lines among some gallinaceous bird species (e.g. willow ptarmigan, capercaillie and black grouse) seems to be peaking during the spring season, i.e. adult birds going to reproduce are killed (Bevanger 1995). A second aspect is connected to estimating the landowner's loss when he gets a power line routed across a high quality hunting area. The economic compensation extent due to reduced quality of a small game hunting ground is a question frequently debated by both the landowners, the grid owner and the consenting authorities (Brøseth & Bevanger in print).

3.2 Research area and methods

Very low densities of capercaillie and black grouse together with very resource demanding field work in Bangdalen (cf. 2.2), made it necessary to select a new study site (a 300 kV transmission line in Ogndalen, Steinkjer municipality) (**Figure 1**). Thus, the field work was delayed with approximately one year, and this subproject will have a final field data sampling period in spring 2014.

The study area is approximately 28 km^2, being transected by a 300 kV transmission line. Here the population of capercaillie *Tetrao urogallus* and black grouse *Tetrao tetrix* is censused by transect sampling of droppings in relation to a 7.1 km long section of the transmission line. During spring before snow melt, 15 transect lines (each 4 km long) are patrolled for data sampling by one person using cross country ski. During the transect line census, visual observations of tracks/droppings in the snow are conducted on both sides of the line (**Figure 10**). All droppings assumed to come from capercaillie or black grouse are collected in small plastic tubes with silica grains for rapid drying for later DNA analyses. GPS position and perpendicular distance to the transect line are used to estimate the effective search width for density and population estimates in the study area.

DNA from droppings are analyzed with several autosomal microsatellite loci to distinguish among individuals; seven in capercaillie (BG15, BG18, sTuD3, sTuD1, sTuT3, sTuT4 and sTuT1) and six in black grouse (BG15, BG18, BG16, sTuD1, sTuT3 and sTuT4). For sex determination, we are using one sex-chromosome specific marker (P2P8).

The only efficient way to collect data on collision victims in low-density forest habitats is to count dead birds in the power-line corridor, by crisscrossing beneath the phase conductors in the clear-cut area. To increase the efficiency in the effort to find dead birds, searches should be accompanied by a special trained dog (Bevanger 1999). A wachtel dog, born in September 2009, was purchased and trained for the project. A 7.1 km section of the 300 kV transmission line crossing through the research area has been searched for dead birds once a week during the period March-May, and every second week during the period September-February. As by January 6 a total of 50 collision victims have been recorded. At least 14 bird species are among the victims, of which 8 are capercaillie and 13 black grouse (**Table 1, Figure 11**).

By DNA identification of the collision victims, estimates of the power-line related mortality rates in the population have been obtained and annual survival estimates from the capture-recapture DNA design have been used to compare the risk of collision mortality relative to the distance to the power line.

3.3 Preliminary results and conclusion

In March 2011 (**YEAR 1**) the study area was surveyed for a total of 116 km and 53 droppings were collected for DNA analysis. The analysis success rate was 81 %, which is very good The majority of the failure samples were from droppings with possible mix-up species like willow ptarmigan (*Lagopus lagopus*) and hazel grouse (*Bonasa bonasia*). A total of 18 different black grouse and 8 capercaillie specimens were identified from the samples respectively. Based on a calculated effective search width (ESW) of 26 m, the population in the study area was estimated to be 86 black grouse (3.0 birds/km^2) and 34 capercaillie (1.2 birds/km^2) (**Table 2**). Because of extreme snow melting conditions a second data survey in spring 2011 had to be cancelled.

In year 1 14 search patrols for dead birds with the trained dog was conducted, and a total of 29 sites with bird/bird remains from collision victims was identified. DNA analysis was used to identify 19 different individuals from six species among the bird/bird remains, among others 4 capercaillie and 4 black grouse.

Table 1. *Bird collision victims recorded during patrols along a 7.1 km section of a 300 kV transmission line in Ogndalen (April 2011-January 2014)*.

Species	Recorded	Sex
Capercaillie	27.04.2011	Female
Willow ptarmigan	27.04.2011	
Redwing	04.05.2011	
Willow ptarmigan	04.05.2011	
Willow ptarmigan	04.05.2011	
Redwing	04.05.2011	
Black grouse	10.05.2011	Male
Redwing	10.05.2011	
Black grouse	26.05.2011	Female
Northern wheatear	08.09.2011	
Black grouse	08.09.2011	Female
Redwing	08.09.2011	
Willow ptarmigan	06.10.2011	
Redwing	06.10.2011	
Capercaillie	25.10.2011	Female
Capercaillie	25.10.2011	Female
Black grouse	07.11.2011	Female
Willow ptarmigan	23.11.2011	
Capercaillie	23.11.2011	Female
Capercaillie	16.04.2012	Female
Black grouse	10.05.2012	Female
Dabbling duck	21.05.2012	Female
Eurasian teal	31.05.2012	Male
Willow ptarmigan	22.10.2012	Male
Redwing	22.10.2012	
Fieldfare	22.10.2012	
Willow ptarmigan	06.11.2012	Male
Pine grosbeak	06.11.2012	Male
Waxwing	06.11.2012	
Capercaillie	06.11.2012	Female
Willow ptarmigan	20.11.2012	Male
Common redpoll	20.11.2012	
Capercaillie	10.01.2013	Female
Black grouse	22.03.2013	Female
Black grouse	22.03.2013	Female
Black grouse	16.04.2013	Female
Turdus sp.	08.05.2013	
Black grouse	08.05.2013	Male
Redwing	08.05.2013	
Black grouse	08.05.2013	Female
Black grouse	08.05.2013	Male
Common redpoll	15.05.2013	
Song thrush	15.05.2013	
Golden eagle	15.05.2013	Male
Black grouse	15.05.2013	Male
Common redshank	23.05.2013	
Song thrush	30.05.2013	
Redwing	09.10.2013	
Black grouse	18.12.2013	Male
Capercaillie	06.01.2014	Male

In March 2012 (**YEAR 2**) two data sampling periods with line transects and droppings for DNA analysis were completed. During 229 km of transect sampling on snow, 126 droppings for DNA analyses were collected. The analysis had a success rate of 76 %. A total of 29 different black grouse and 23 capercaillie specimens were identified from the samples respectively. The population in the study area was estimated to be 70 black grouse (2.4 birds/km^2) and 56 capercaillie (1.9 birds/km^2) (**Table 2**).

In year 2 a total of 17 search patrols for dead birds were conducted. A total of 20 sites with bird/bird remains from collision victims in the study period were identified. DNA analysis was used to identify 13 different individuals from nine species among the bird/bird remains, among others 3 capercaillie and 1 black grouse. In March 2013 (**YEAR 3**) three data sampling periods with line transects and droppings for DNA analysis were completed. During 355 km of transect sampling on snow, 146 droppings for DNA analyses were collected. The analysis had a success rate of 90 %. A total of 63 different black grouse and 15 capercaillie specimens were identified from the samples respectively. The population in the study area was estimated to be 99 black grouse (3.4 birds/km^2) and 24 capercaillie (0.8 birds/km^2) (**Table 2**). As of October 24 2013 a total of 12 search patrols for dead birds had been conducted in the third study year, and 19 sites with bird/bird remains from collision victims have been identified. DNA analysis identified 16 different individuals from eight species among the bird/bird remains, among others 1 capercaillie and 7 black grouse.

DNA analyses based on dropping collection seem to provide reliable capercaillie and black grouse population estimates within a practicable timeframe and reasonable costs. The method would also reduce the possibility for overestimating the population size and the number of collision victims. There are several biases associated to dead bird collection in power-line corridors, and sometimes it is difficult to decide whether separate feather and bird remains come from same or different fatalities. With DNA analyses, the subjectivity is eliminated. The overall (preliminary) conclusion with respect to population impact is that the recorded mortality for capercaillie in 2011-2013 are estimated to reduce the population size between 4.2-11.8 percent, and 1.4-8.1 percent for black grouse. This additional mortality should be taken into account when e.g. issuing hunting licenses.

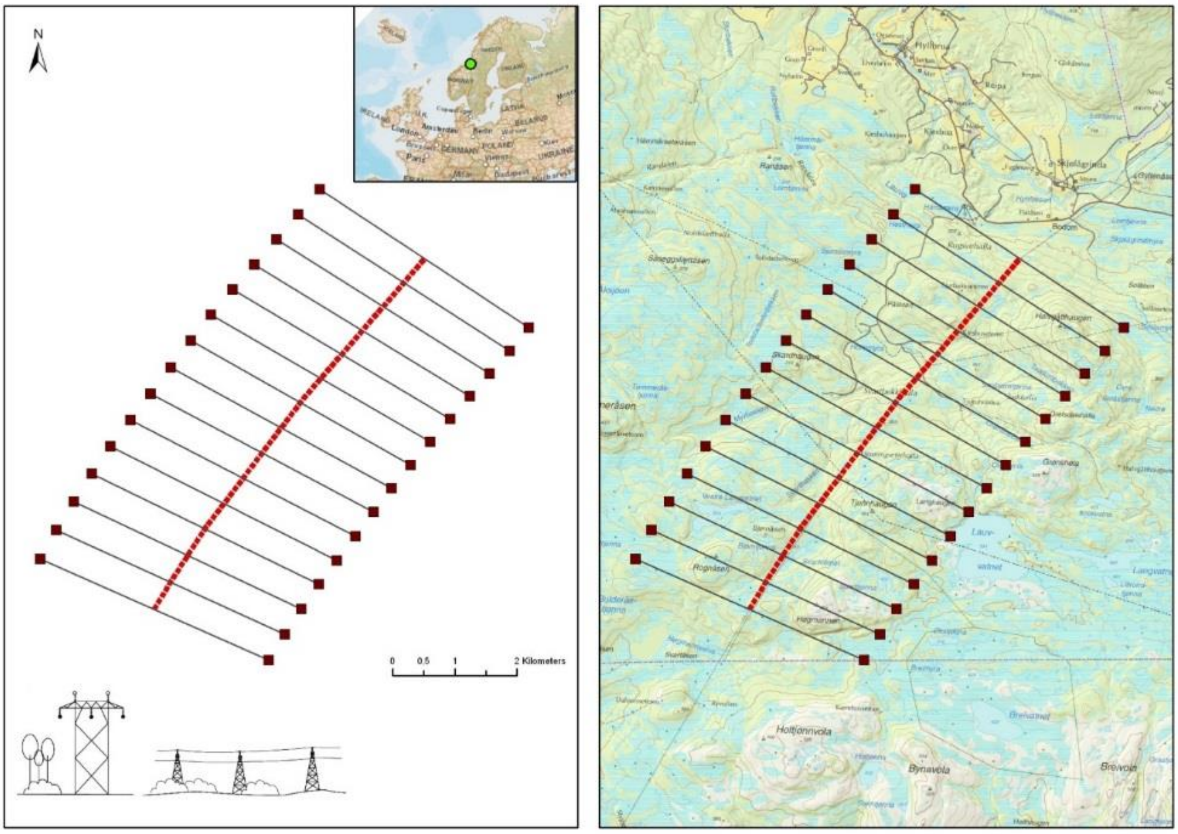


Figure 10. *Study area in Ogndalen (approximately 28 km^2) in connection to a 7.1 km 300 kV transmission line section (red line). Capercaillie and black grouse have been censused along 15 lines (each 4 km) to collect droppings for DNA analyses together with observations of birds flushed.*

Table 2. *Estimates of capercaillie and black grouse densities in a 29 km^2 study area in Ogndalen, Steinkjer municipality, Central Norway.*

Year	Areas searched (km2)	Capercaillie density (no/km^2)	Capercaillie number	Black grouse density (no/km^2)	Black grouse number
2011	6.07	1.2	34	3.0	86
2012	12.02	1.9	56	2.4	70
2013	18.61	0.8	24	3.4	99

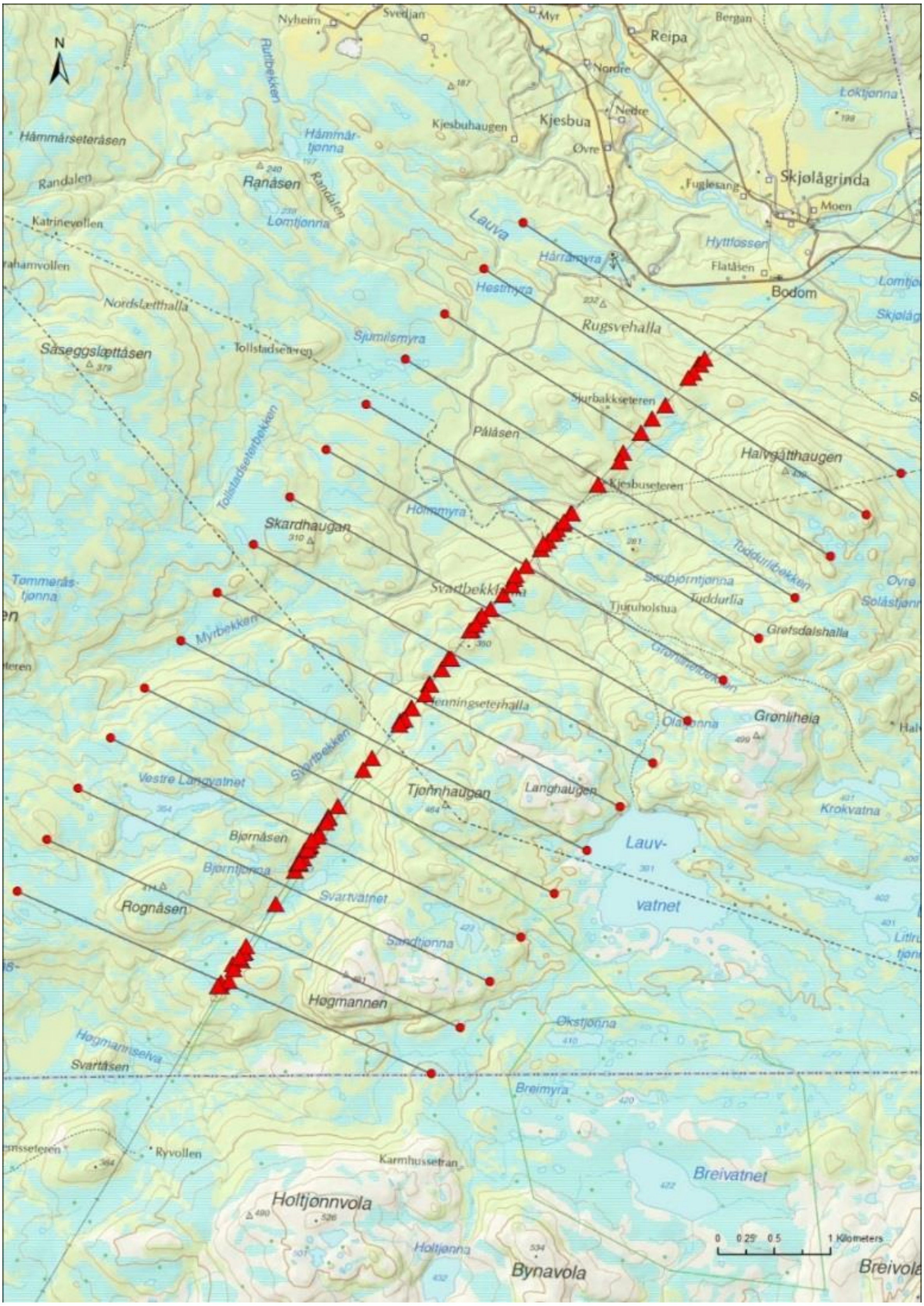


Figure 11. *Dead birds recorded along a 7 km transmission line section in Ogndalen, Steinkjer municipality Central Norway (2011-2013).*

4 Bird collision hot spots

4.1 Background

Gallinaceous birds together with some other species groups are proved to be over-represented among power-line collision victims (Bevanger 1994a, 1995, 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 influencing 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 is the basement for modelling how birds use the terrain, and thus enable – by means of GIS-tools - to predict topographic structures and habitats that should be avoided when new power lines are routed.

4.2 Methods

Over the last 25 years several projects in Norway have sampled qualitative and quantitative data on birds colliding with power lines (Bevanger 1988c, 1990, a,b, 1993, 1994, 1995, Bevanger et al. 1998). Data that will be reanalysed derives from five counties, i.e. Finnmark, Sør-Trøndelag, Hedmark, Oppland and Buskerud. Both the power-line sections patrolled and the sites where dead birds have been located are geographically referred for further GIS analyses and modelling.

In connection to the project on gallinaceous bird population responses to power-line induced mortality (cf. Chapter 3) a wachtel dog breed was bought and trained to find dead birds. A standard set of parameters are recorded in connection to the spots where bird casualties are located.

At the outset a third set of data for the bird-collision hotspot project was planned to come from a national database on dead birds (cf. Chapter 5). Unfortunately, so far the data volume has not met our expectations. Thus, it is not clear yet if these data will be of any use in connection to this subproject.

4.3 Results

Due to low capacity among the NINA GIS experts the analysing part of the project is delayed, and the result will be published at a later stage, however the analysing process is in progress.

5 Utility structures and bird casualties – a national reporting system

5.1 Background

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 characterising both the 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.

5.2 Methods

In 2009 a functional prototype of the web application for registering dead birds (**Figure 12**) was developed. It incorporated topographical maps, and had the possibility of overlaying power-line maps. Some geocoding conversion functions were incorporated and it would be possible to upload pictures of recorded dead birds.

Although the functional prototype of the database was finalised in 2009 (Bevanger et al. 2010), NINA addressed the possibilities to co-operate with The Norwegian Biodiversity Information Centre (NBIC) in early 2010. The NBIC already had a species observation portal – www.artsobservasjoner.no - having become a popular web site and accessed by people contributing with hundreds of observations daily (**Figure 13**). This system is also adopted by the Norwegian Ornithological Society (NOF) which is part of Bird Life International. This is an organisation with a large number of members with solid bird knowledge that also can be activated to undertake specific data sampling task. By making some adjustments of the activity list for death causes in www.artsobservasjoner.no it was possible to use the NBIC observation portal to collect data on dead birds as well.

5.3 Results

The number of reported bird casualties due to collisions with power lines and electrocution has been rather stable, with 25 both in 2011 and 2012, and 33 in 2013.

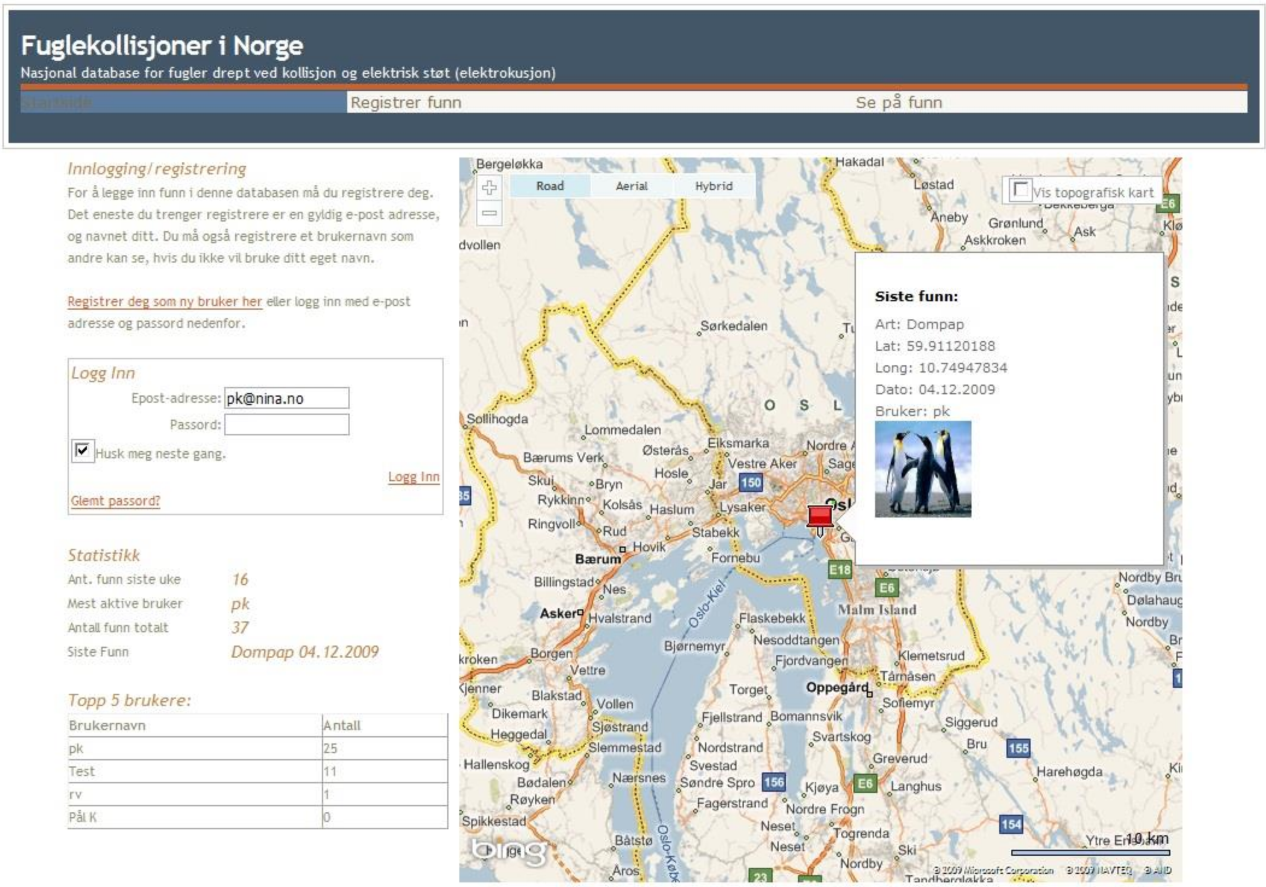


Figure 12. *Screenshot of the web application for registration of recorded dead birds.*

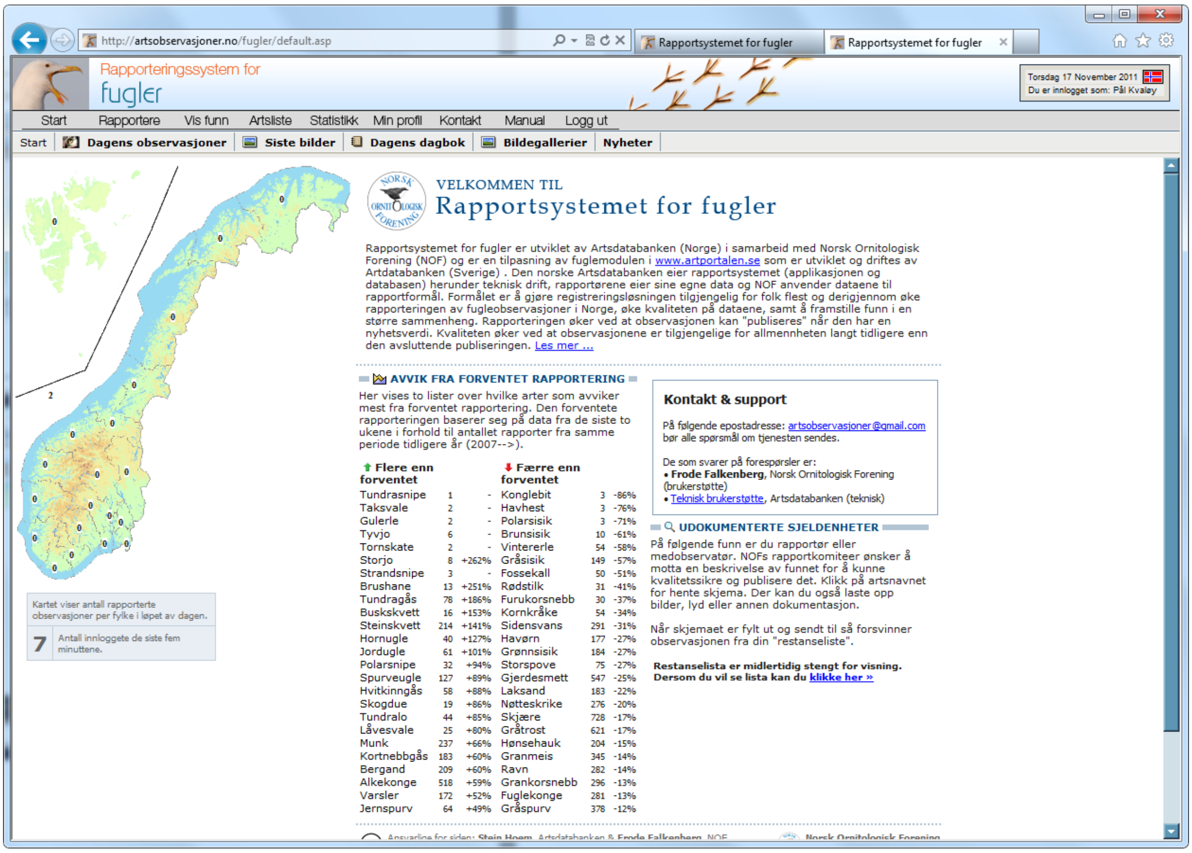


Figure 13. *The Norwegian Biodiversity Information Centre has a species observation portal – www.artsobservasjoner.no having become a very popular web site and being accessed by several people contributing with hundreds of observations daily.*

6 A Least Cost Path (LCP) toolbox for scoping and optimal routing of power lines

6.1 Background

Identifying the “optimal route” when planning to build a new power line is a highly challenging exercise. The great complexity of formal and informal stakeholder interests at different geographical levels has to be identified, organised and handled through standardized impact assessments. Additionally, legal, technological and financial criteria’s have to be analysed prior to the final decision about how to route the new power line. The intention of this project has been to demonstrate how such multi-criteria analysis efficiently can be performed with LCP in planning and decision-making of power-line routing.

6.2 Methods

The least cost path (LCP) methodology helps to identify the path and scoping corridor of least resistance between two locations over a cost index surface where the cost index is a function of distance and user-defined criteria (e.g. distance to homes related to electromagnetic radiation). A cost index surface may also be explained as an aggregated conflict level measure across the terrain surface. Routing of power lines should be avoided in areas where the aggregated conflict level is high and preferably located in areas where the aggregated conflict level is low.

The LCP methodology has been applied in GIS for many years and very little have been changed with respect to the technical approach from its earliest use, on contrary the procedures for calibrating and weighting model criteria have changed rapidly (Berry 2007). Expert oriented research techniques such as Delphi and Analytical Hierarchy Processes has successfully been involved to achieve consensus about criteria, criteria values and weights in power-line routing projects in the USA (e.g. Electric Power Research Institute 2006, Terna 2012).

NINA has adapted and refined the principles and approach of the AEAM-methodology (Adaptive Environmental Assessment and Management: Holling (1978), Hansson et al. (1990)) for use in dialogue processes for assessments of landscape and environmental impacts. The participatory scoping process is based on dialogue where different stakeholders attend. The step-by-step process starts with a holistic view of the current situation and scope down by identifying relevant drivers, thematic content, criteria, criteria values and weights. This dialogue methodology has proved to be an important tool, if implemented early in a planning process, to avoid potential conflicts and to increase the public transparency in the decision processes for development of technical infrastructures like power lines. The methodology has been implemented in a wide range of applications such as scenario development, natural resources conflicts, environmental impact assessment, and ecosystem service indicator scoping (Thomassen et al. 2007; Thomassen & Skei 2007, Thomassen et al. 2008 a, b, Thomassen et al. 2009 a, b, Thomassen & Hindrum 2011). To ensure a user oriented bottom-up approach we decided to implement this dialogue methodology in the work with the OPTIPOL LCP toolbox.

To calibrate the variety of identified stakeholders' interests and legal requirements into standardized criteria for calculation of cost index surfaces in non-restricted areas, the various criteria must be transformed into stakeholder's degree of acceptance measured on a continuous scale from 0 to 1 using Fuzzy logic theory (Zadeh 1965, Zadeh et al. 1996). Restricted areas where routing of power lines is legally prohibited may be excluded from the calculation and designated as “no data areas” if relevant. The practical implication of this in GIS basically consists of three steps. First a discrete cost index surface has to be developed for each criteria in order to indicate the relative preference for routing in any location within the study area. Secondly an accumulated cost index 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 optimal path and corridor (areas with least cost index values) between two locations on the accumulated cost index surface have to be calculated.

Measuring various qualitative and quantitative criteria in this way is very challenging. Questions could be raised whether all kinds of criteria really can be measured at all. For example are Samii reindeer herding interests very challenging to measure because of its dynamic land use form adapted to seasonal and climatic fluctuations. Another example is perception of symbolic landscapes because of the complexity of subjective interpretations made by individuals. Despite these kinds of challenges we believe that most stakeholders' degree of acceptance could be generalized, quantified and measured with the use of Fuzzy logics (**Figures 14, 15, 16**). What is the acceptable placement of power lines on high altitude ridges in order to avoid and/or reduce silhouette effects and visual disturbance for exposed observers within visibility range? Do we want to totally avoid silhouette effects and visual disturbance or could we accept some level of silhouette effects and visual disturbance? An absolute criteria definition could be that the only acceptable power line placement is 1 post height below the top of the ridges (i.e. 30 meters). This will give a degree of acceptance of 1 (vertical placement of power lines < than 30 meters below the ridge top is not acceptable) and 0 (vertical placement of power lines => than 30 meters below the ridge top is acceptable). The function will be binary (green graph). If defining the criteria in a more flexible way saying it is unacceptable to route the power lines at the top of the ridges, while 15 meters below is fairly acceptable and 30 meters (1 tower height) below are the most acceptable, a more continuous degree of acceptance (red graph) is needed.

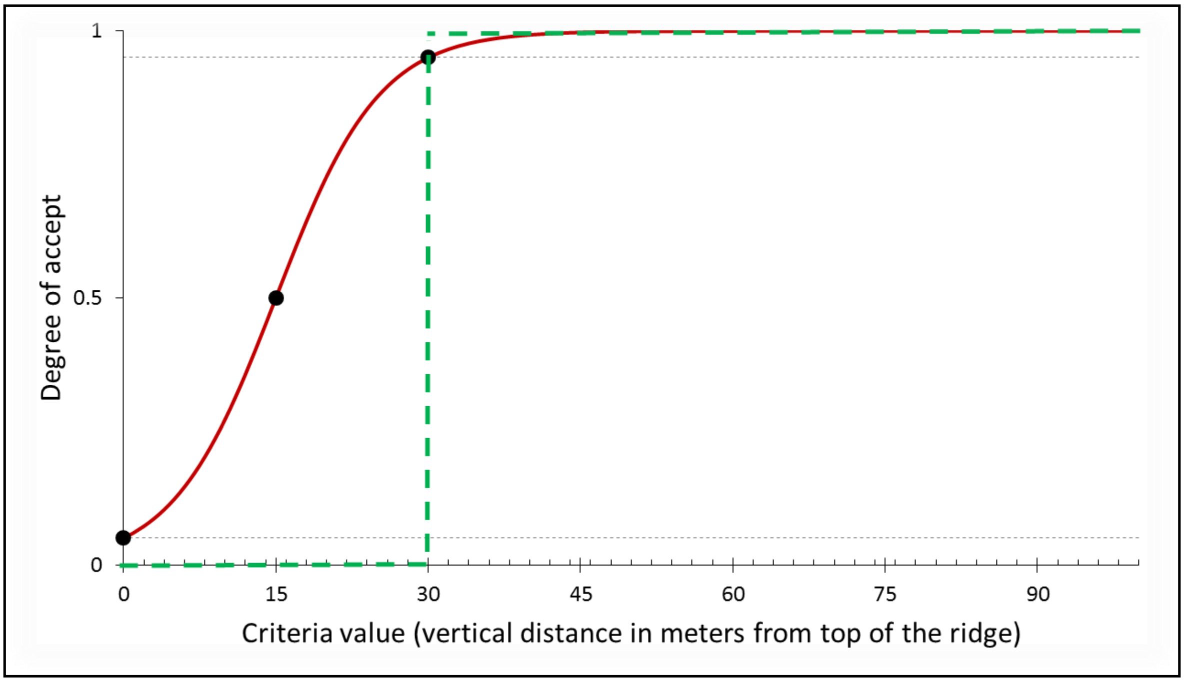


Figure 14. *Measuring degree of acceptance: Construction of power lines on high altitude ridges in order to avoid and/or reduce silhouette effects and visual disturbance (green graph is the binary and red graph is the continuous fuzzy logic function).*

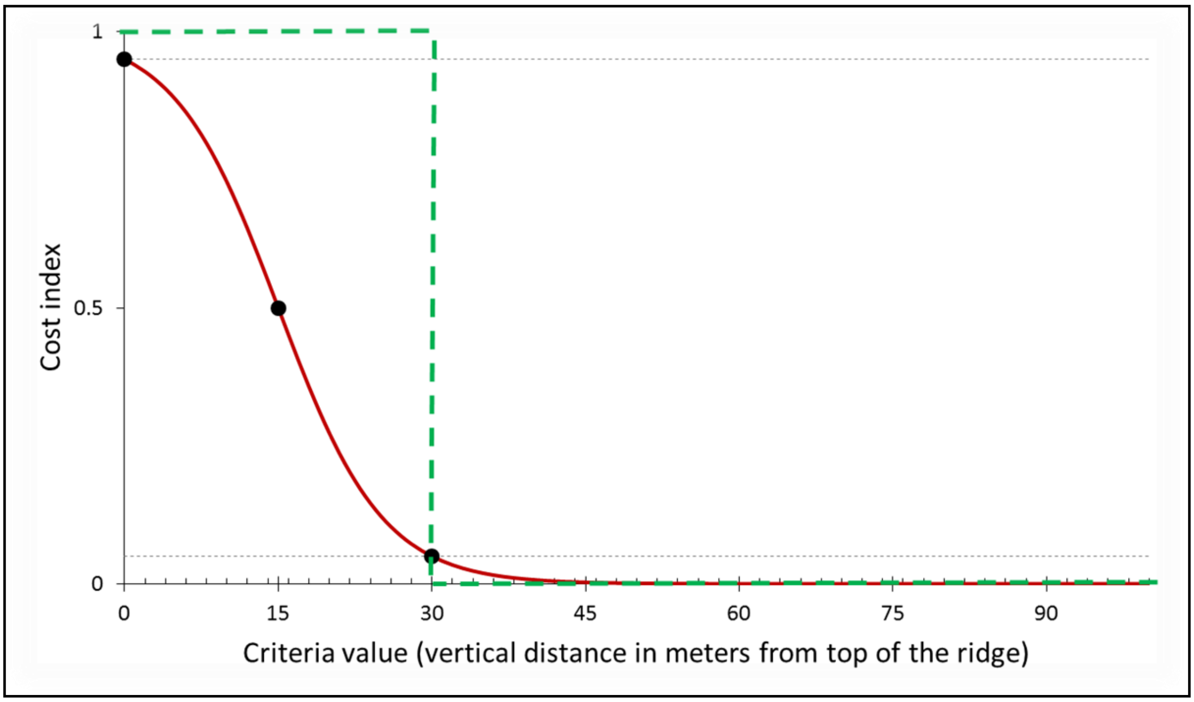


Figure 15. *Cost surface index calculation: Construction of power lines on high altitude ridges in order to avoid and/or reduce silhouette effects and visual disturbance (green graph is the binary and red graph is the continuous fuzzy logic function).*

Assuming that locating the power line 15 meters below the top of the ridge is acceptable, we can apply the criteria value and calculate the cost surface for this criterion. Applied on a hill-shade map the cost index surface map identifies the spatial distribution of conflict levels (1 - degree of acceptance) from green (low conflict level) to red (high conflict level (**Figure 16**).

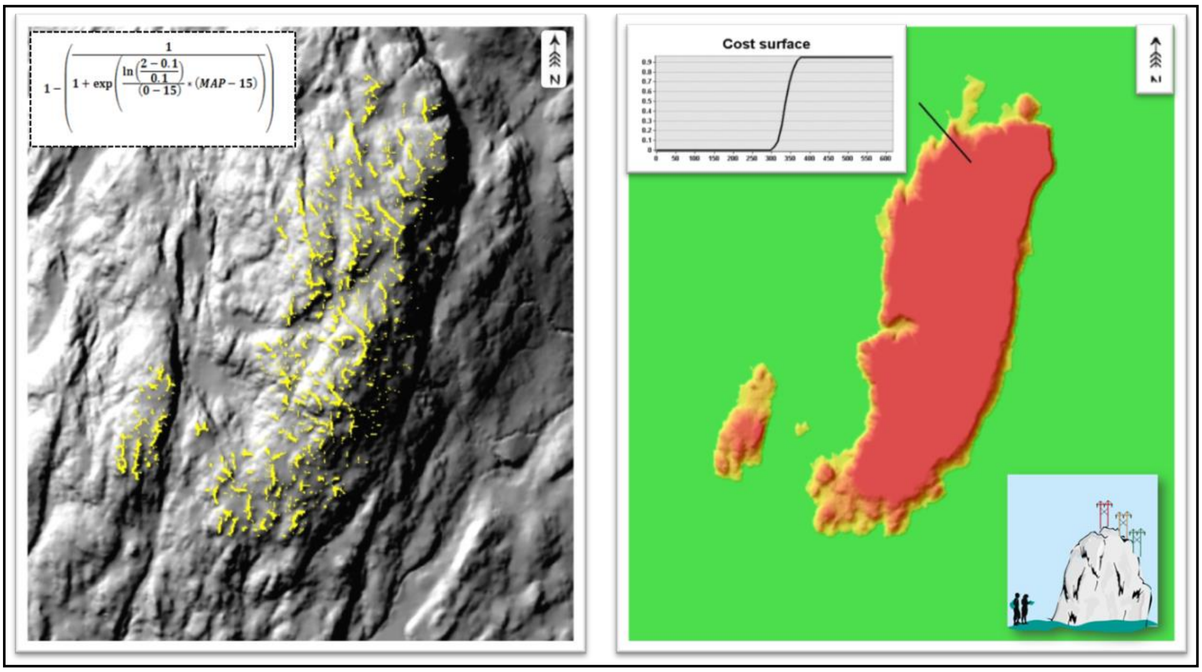


Figure 16. *Cost index surface map displaying the spatial distribution of conflict levels from green (low conflicts) to red (high conflicts in accordance with the criteria on silhouette effects and visual disturbance (left map show high-altitude ridges (in yellow) and right map shows the Cost index surface map).*

All relevant sub-thematic cost index surfaces are calculated in this manner based on the stakeholder's degree of acceptance. In reality, it can be hard to get consensus from all stakeholders on one specific criteria value. For process scoping it is extremely important to identify the geographical areas of a given criteria value disagreement. To do so we are using simple statistics to measure average cost levels and cost variation. The most preferred areas (agreement on a low conflict level) are those with a low mean cost and a low cost variation. Areas to avoid (agreement on a high conflict level) are the ones with high mean cost and low cost variation. Areas with a high cost variation (indicating disagreement in criteria value estimation) indeed should be further assessed.

The sub-thematic cost index surfaces then have to be weighted percentually according to their relative importance and summarized into thematic cost index surfaces. The thematic surfaces are in turn weighted percentually according to their relative importance and summarized into cost index surfaces for each perspective (ecological, economic, society and technological). Finally, all perspective cost index surfaces are weighted percentually according to their relative importance and summarized into a total aggregated cost index surface. Restricted areas may be excluded from the calculation as no data areas if relevant.

This spatially explicit multi-criteria approach is highly flexible. Most stakeholder criteria have a geospatial context. If these criteria are well defined and measurable, it is very easy to implement the criteria in the calculations. The method is also very flexible as it allows different point of views to be included. The valuable output of this is that the spatial extent of the stakeholder's interests can be directly identified in a map. In reality, it is hard to model the ideal placement of a power line from pole to pole. Local field issues will have to be taken into account at later stages of the planning process. Even though the OPTIPOL LCP can model an optimal path our aim is to foremost focus on the scoping corridor identified by the toolbox. This corridor can assist to scope the further EIA-process and outline the project area at a very early stage of a power line routing project.

6.3 Results

6.3.1 The validation case study

The OPTIPOL LCP Toolbox pilot version (1.0) was designed for a local case study validation in April 2012. This was requested by the Norwegian Water Resources and Energy Directorate and the Norwegian national main grid owner/operator Statnett in order to validate the OPTIPOL LCP Toolbox in a real world case based on existing knowledge from the previous environmental impact assessment documents (EIA) prior to construction. NVE and Statnett selected the 420 kV transmission line project finalized in 2005 between Klæbu and Viklandet in central Norway for the validation exercise. To save time and work in digital preparation of the historical EIA-data from 2001 and 2002 it was decided to focus on a part of the existing power line in the five municipalities Trondheim, Klæbu, Skaun, Melhus and Orkdal.

A group of invited stakeholders (NGO`s, municipalities, regional and governmental management, scientific research institutions, consultants and the energy industry) was invited to participate in facilitated dialogue seminars in order to validate the relevance of the toolbox. The stakeholders were also asked to identify relevant content, define relevant criteria, criteria values and weights for the local validation exercise. The first stakeholder dialogue seminar was successfully held in Stjørdal 23-24th of May 2012. During the first Stjørdal seminar the stakeholders acknowledged the dialogue and toolbox approach as very important, if implemented early in a planning process, in order to reduce potential conflicts and to increase the public transparency of decision processes in power line routing. A second dialogue seminar was held in Stjørdal on November 20th 2012. The list of invited participants to this second seminar was based on the list of invited participants from seminar one, supplemented with some additional stakeholders. The findings from the dialogue seminars are summarized in online NINA-reports (Thomassen et al. 2012, 2013). In addition to these two dialogue seminars we organized a national online questionnaire during May/June 2013 to assess and validate the criteria values and weights. Subsets of the most relevant findings from the two dialogue seminars and the online user survey are implemented as default guidance criteria in version 2.0 of the LCP-toolbox. The frameworks of the stakeholder's involvement are illustrated in **Figure 17**.

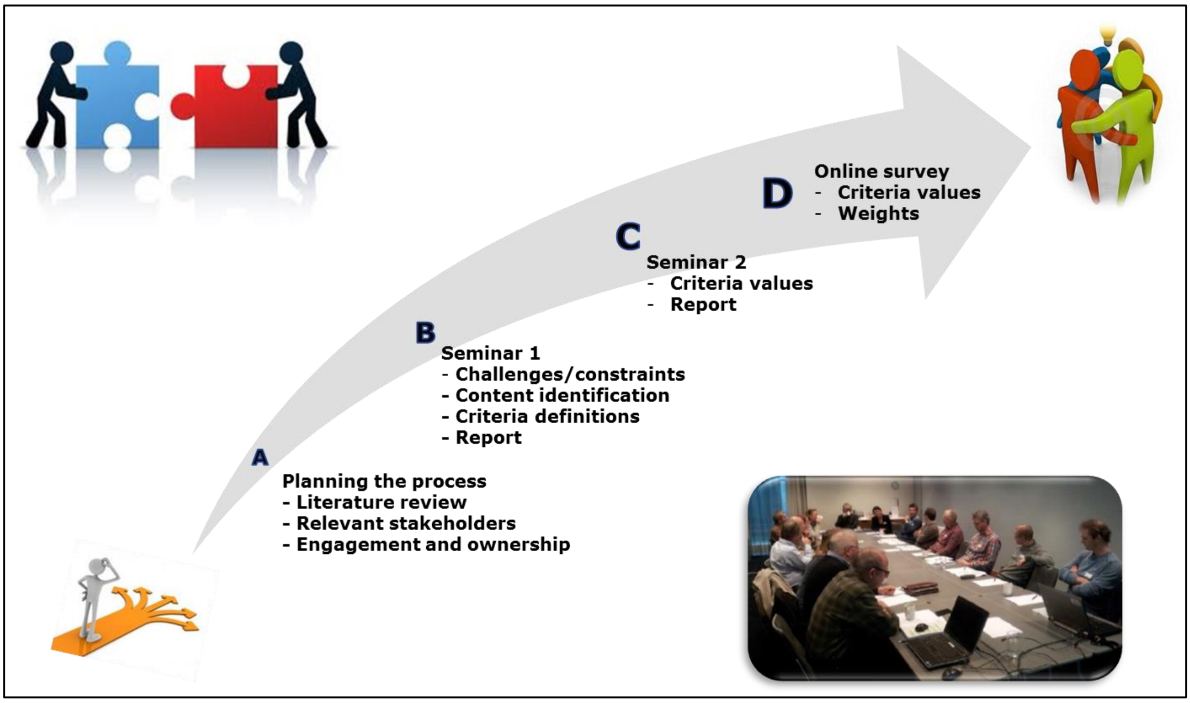


Figure 17. *Framework for the stakeholder dialogue seminars and the online survey.*

The historical and analog EIA-material were digitized and aggregated into cost surface index maps according to the applied criteria and the stakeholders' degree of acceptance for each of these criteria (**Figure 18**).

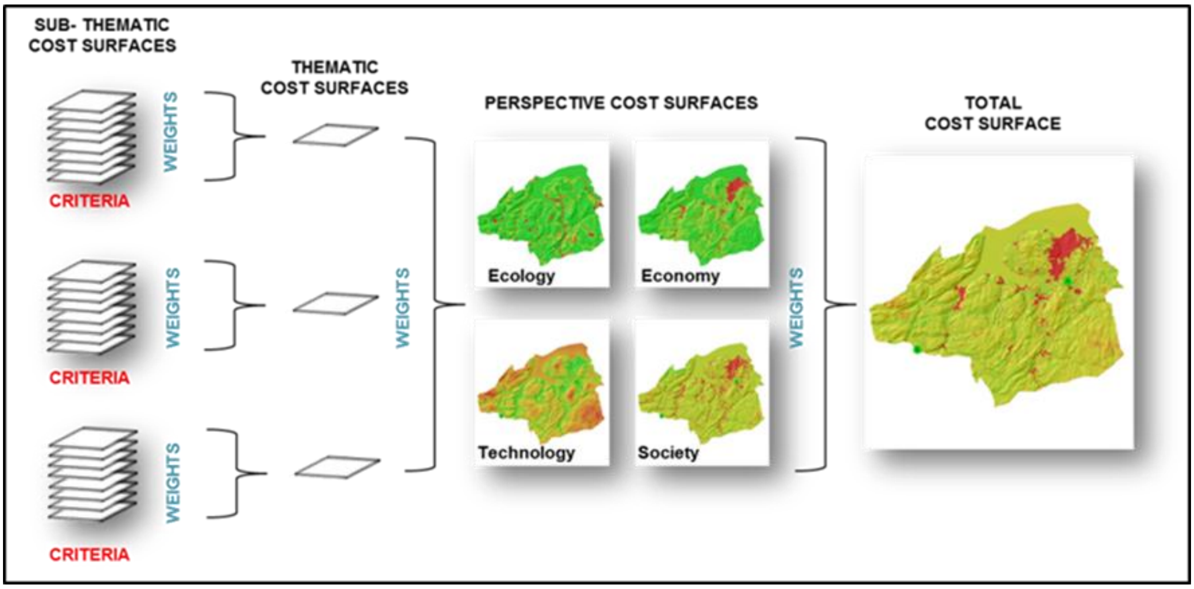


Figure 18. *Aggregated cost index surface maps. The heatmap colours illustrate conflict levels from 0 (green) to 1 (red).*

Comparing the separate LCP calculations for each perspective cost surface with the present power line route we can see how the ecological and economic optimal routes tend to deviate quite a lot from the existing power line route (**Figure 19**). Based on the total cost index surface the toolbox calculated a least cost optimal corridor (thresholded at 0.5 standard deviations) and a least cost path that correlates relatively well with the existing power line route built in 2005 (**Figure 19**).

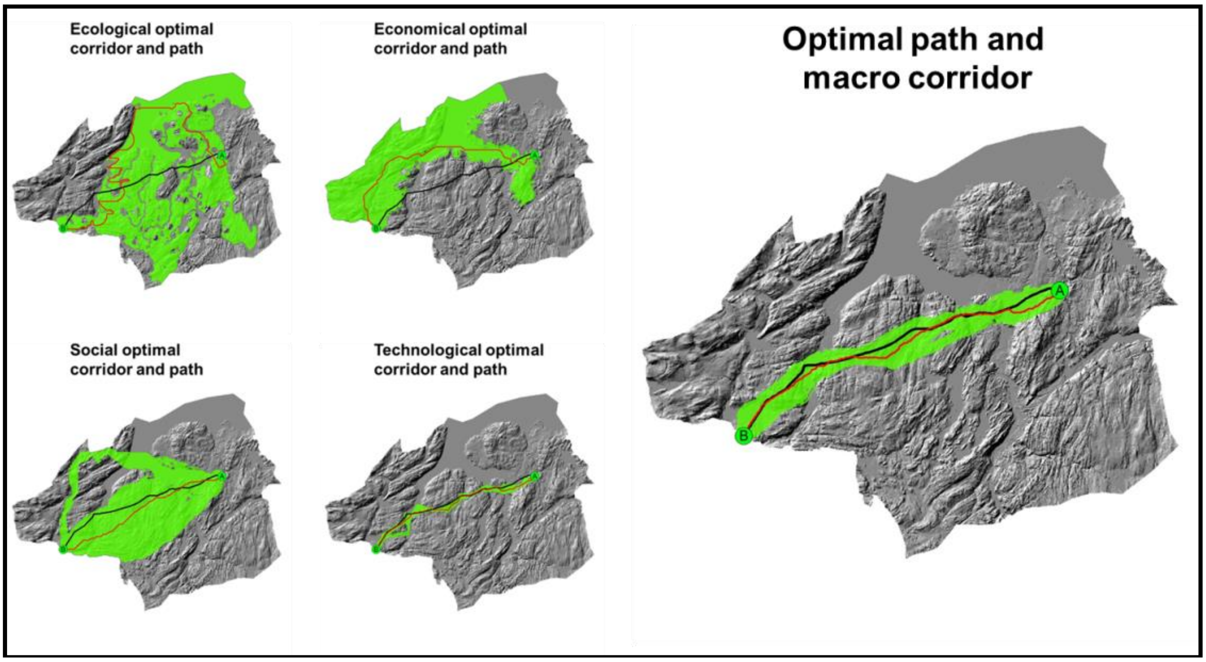


Figure 19. *Validation between the LCP-toolbox and the 420 kV power line project finalized in 2005 between Klæbu (A) and Orkdal (B). Existing power line (black line), modelled least cost path (red line) and modelled least cost corridor for the individual perspectives (in green).*

This case study validation exercise illustrates the advantage of LCP as an effective planning tool that ensures a holistic approach in efficient handling of the multicriteria complexity of a power line routing project. This user directed approach has a great potential for improved efficiency in the preliminary planning stage of a new power-line project. This includes cost optimization, scoping (thematic and geographical) and conflict reduction, which in turn could lead to improved public acceptance and political legitimacy of the final routing decision.

6.3.2 Technical description of the OPTIPOL LCP Toolbox version 2.0

The toolbox is designed for use in ESRI ArcGIS Advanced version 10.2 with the Spatial Analyst extension. The toolbox is developed in ModelBuilder, which is a visual programming language for building workflows that string together sequences of standardized geoprocessing tools. Model-Builder is very effective for executing simple GIS workflows and provides advanced methods for extending standard ArcGIS functionality by creating and sharing models as tools. Each tool can be operated as singular workflows or through an adapted graphical user interface (GUI). The toolbox also uses Python script code for visual organization of output map layers in the dockable table of content list. The toolbox actually contains many toolboxes (**Figure 20**). Each toolbox contain tools for demarcation of a scoping corridor, calculation of criteria maps (social, technological and ecological) and calculation of routing maps.

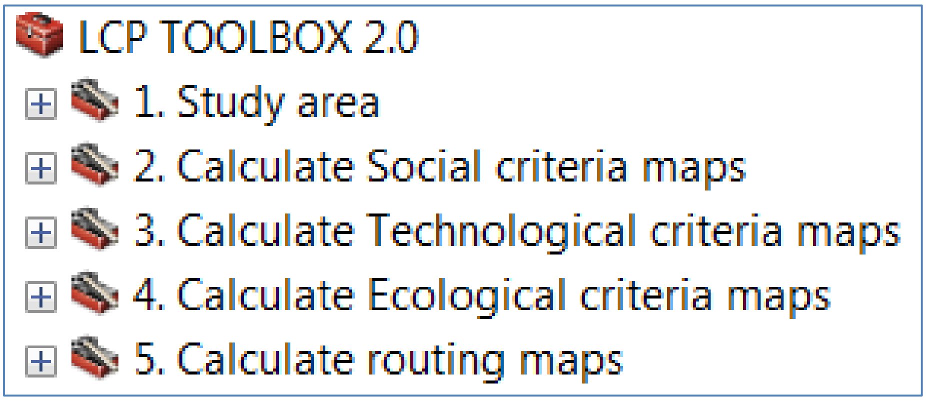


Figure 20. *The OPTIPOL LCP Toolbox.*

6.3.2.1 The OPTIPOL LCP Database

The OPTIPOL LCP File Geodatabase use replicated data from different national data sources:

- The Norwegian Mapping Authority
- The Norwegian Environment Agency
- The Norwegian Water Resources and Energy Directorate
- The Norwegian Directorate for Cultural Heritage
- Statistics Norway
- The Norwegian Geological Survey
- The Norwegian Directorate of Reindeer Husbandry
- The Norwegian Biodiversity Information Centre

Input data are licensed to NINA under the Digital Norway License. Data on sensitive species information are regulated by the “Guidelines for management of geolocated information about biodiversity” from March 2009 (The Norwegian Environment Agency).

The toolbox import spatial input data from a local copy data repository into an ESRI File Geodatabase. This is a Single User Database for individual GIS work in a desktop environment. The File Geodatabase is stored in a file system and has no theoretical size limit (one table can store up to 256 TB of data).

All calculations performed by the toolbox are done in the File GeoDatabase Raster Dataset format with the same resolution as the national digital elevation model (25x25 meters). The basic file geodatabase raster schema has five constituent tables arranged in a hierarchy: The business table is at the top of the hierarchy, while four other subordinate tables store the raster metadata and pixel data. The business table also contains a feature column, which maintains the envelope of the raster. The feature column joins to a feature table that actually stores the feature envelopes. The raster blocks table, the largest, stores the actual pixel information and pyramids. All these tables are stored in a hidden native file format, and are therefore not directly accessible. The raster blocks table stores the pixel data as a column containing long sequences of binary numbers (BLOB), one row per block by band and pyramid level. The bands are tiled into blocks of pixels according to a user-defined dimension - the default is 128 by 128 pixels. Tiling the raster band data enables efficient storage and retrieval of the raster data. The pyramid information is stored according to a declining resolution. By default, the height of the pyramid is defined by the number of levels either by the application or automatically by the system.

6.3.2.2 The OPTIPOL LCP Criteria, criteria values and weights

The toolbox have implemented a subset of the most relevant criteria, criteria values and weights identified as important for planning and environmental impact assessment related to power line routing (section 6.3.1). Where stakeholders expressed disputes on criteria values in the questionnaire, median numbers were selected for use in the toolbox as a consensus value. The list of criteria, criteria values and weights are only meant as guiding values. The subset of criteria, criteria values and weights implemented in the toolbox are not applicable for all regions or scales. It is difficult to make universal criteria sets, thus, it is important to identify relevant criteria, criteria values and weights relevant for the actual study area and scale. Herein lies the great flexibility of the OPTIPOL LCP toolbox, as it is easy to add new, remove or change the underlying models.

When stakeholders emphasize different criteria values for a single criteria it is allowed to add up to 50 different pairs of input values. By default consensus maps and conflict maps are calculated from the input values. This spatial identification of consensus and conflict areas may be important assets in the process scoping.

6.3.2.3 Define a region of interest

The first step in using the toolbox is to define a region of interest (ROI) or study area (**Figure 21**). This can be done either by drawing a polygon in the map or by importing a municipality polygon. The ROI forms the valid extent for the further calculations. The size of the ROI is positively correlated with processing time and the amount of output data.

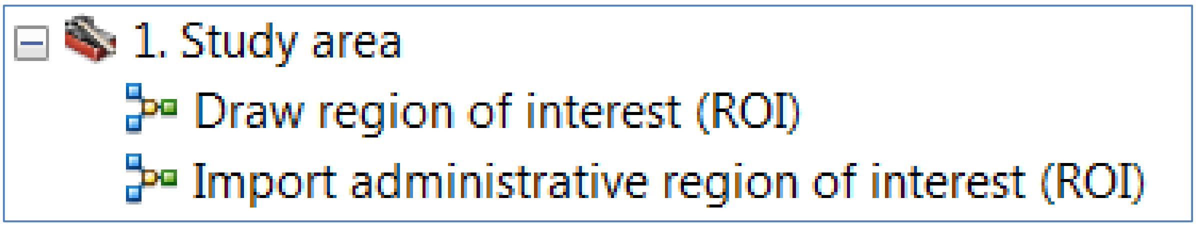


Figure 21. *Defining a study area (region of interest).*

6.3.2.4 Calculate Social criteria maps

The next step is to calculate the Social criteria maps (**Figure 22**). This is a series of calculations where sub-thematic criteria maps are calculated and then weight-summarized into separate thematic criteria maps. All criteria maps are finally weight-summarized into a Social criteria weight sum map (cf. **Figures 23-27** for illustrated examples).

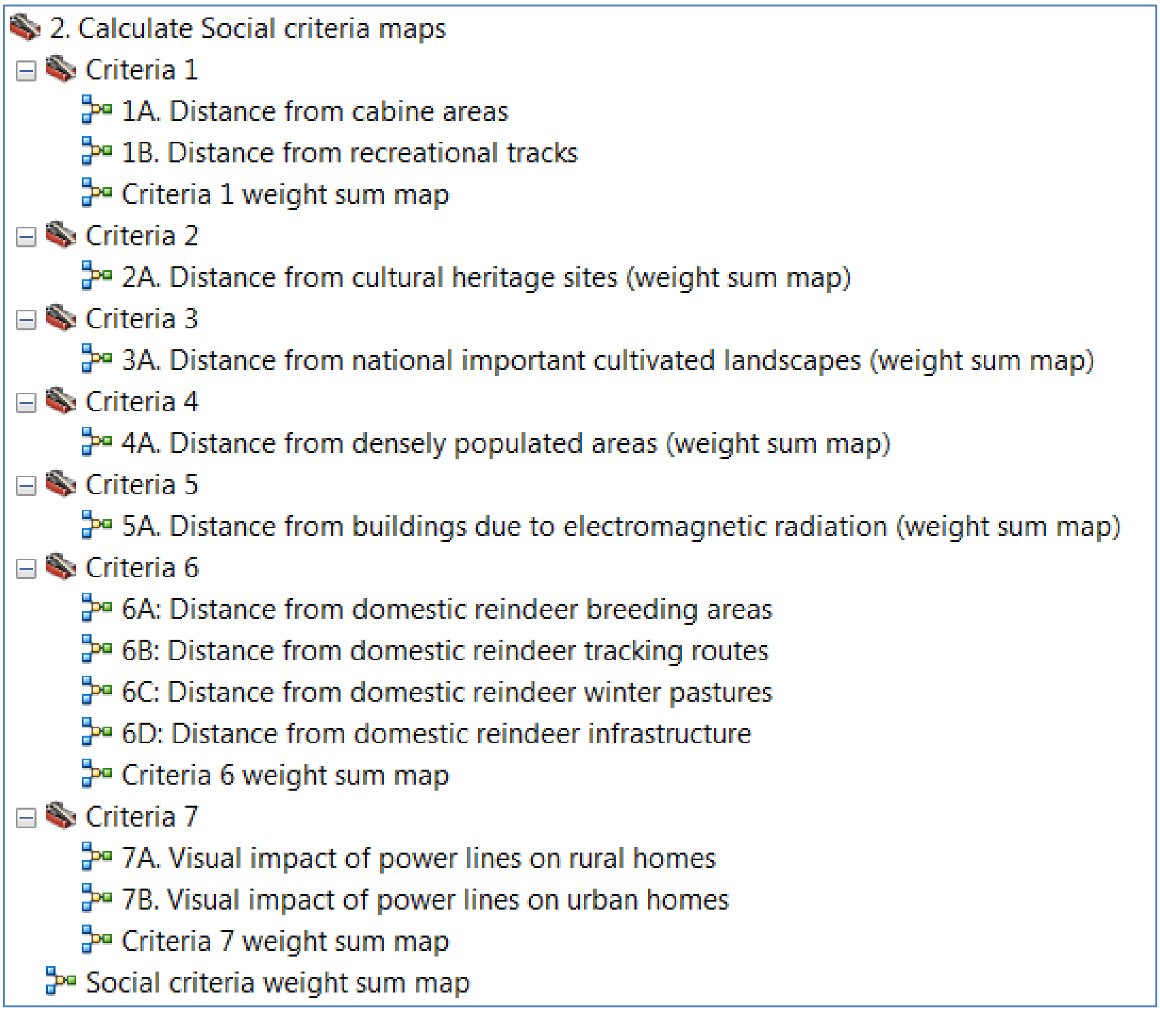


Figure 22. *Calculate Social criteria maps.*

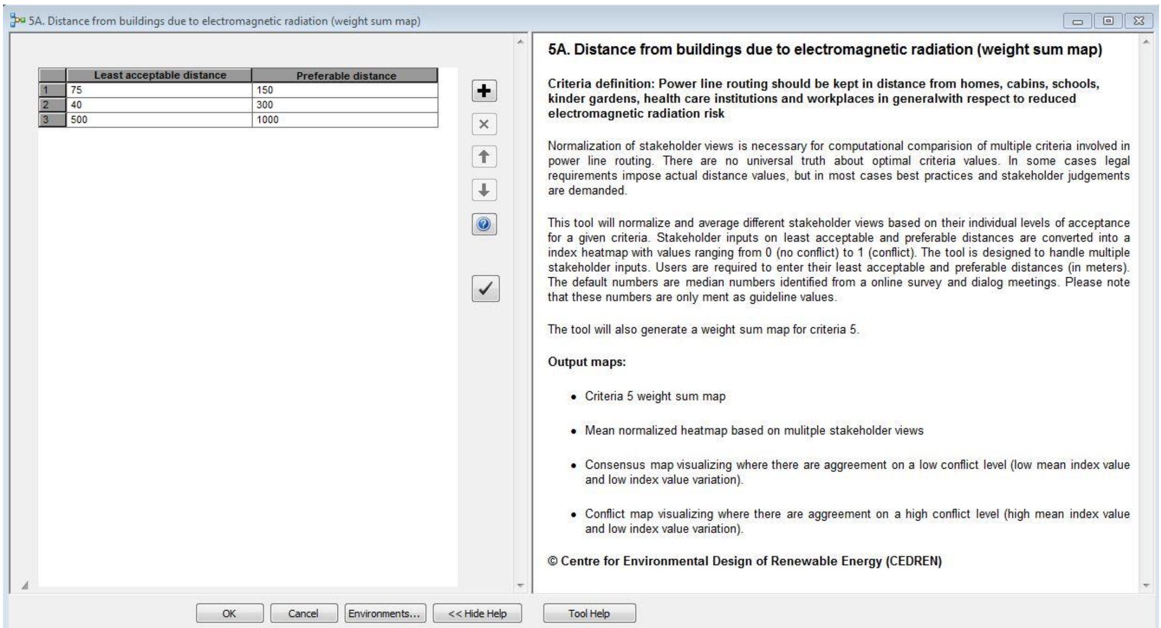


Figure 23. *Example: Calculate Distance from cabin areas with multiple stakeholder inputs.*

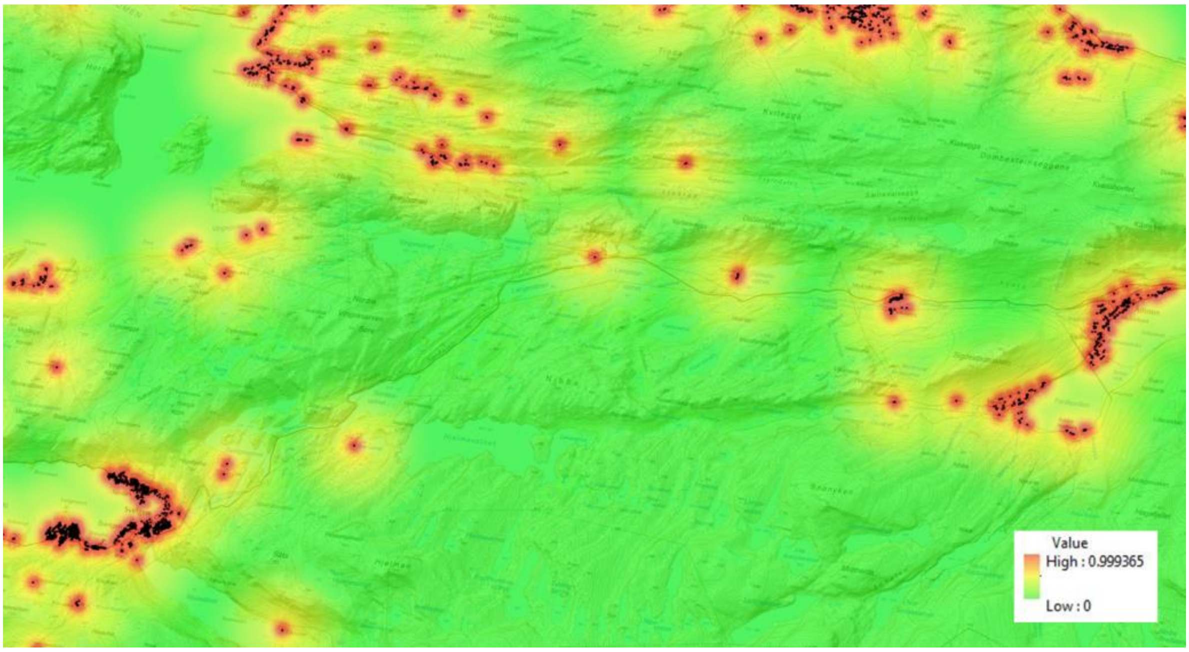


Figure 24. *Example: Mean normalized heatmap for criteria 5a: Distance to buildings due to electromagnetic radiation (Bremanger municipality in western Norway).*

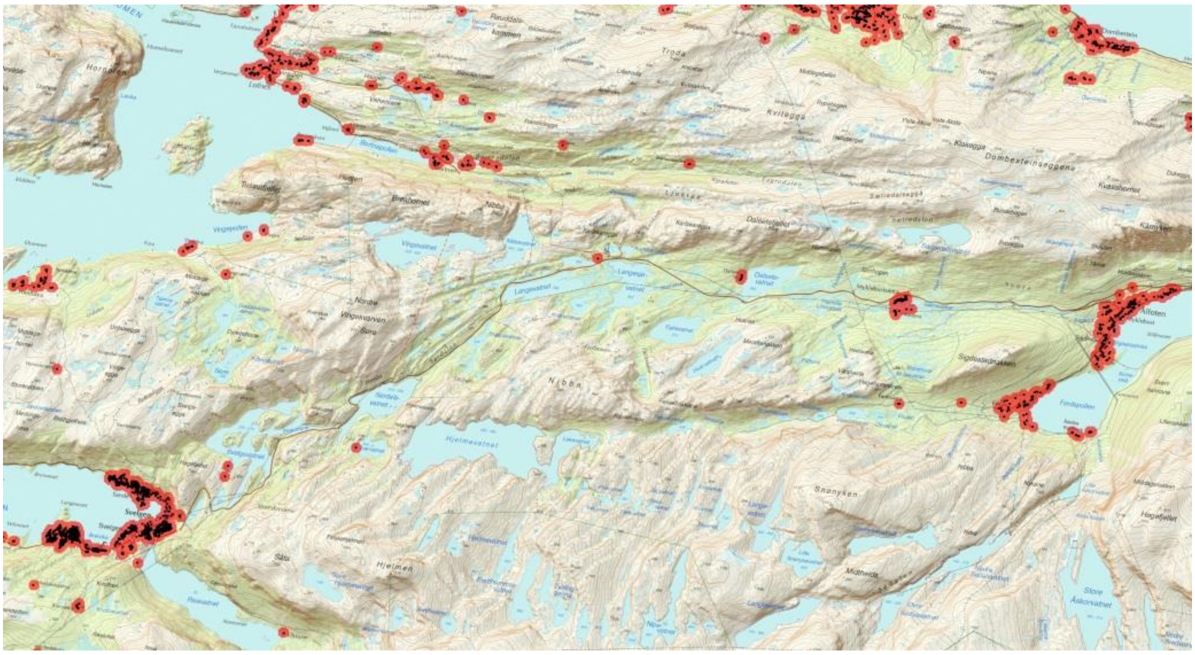


Figure 25. *Example: Conflict map for criteria 5a: Distance to buildings due to electromagnetic radiation (Bremanger municipality in western Norway)*

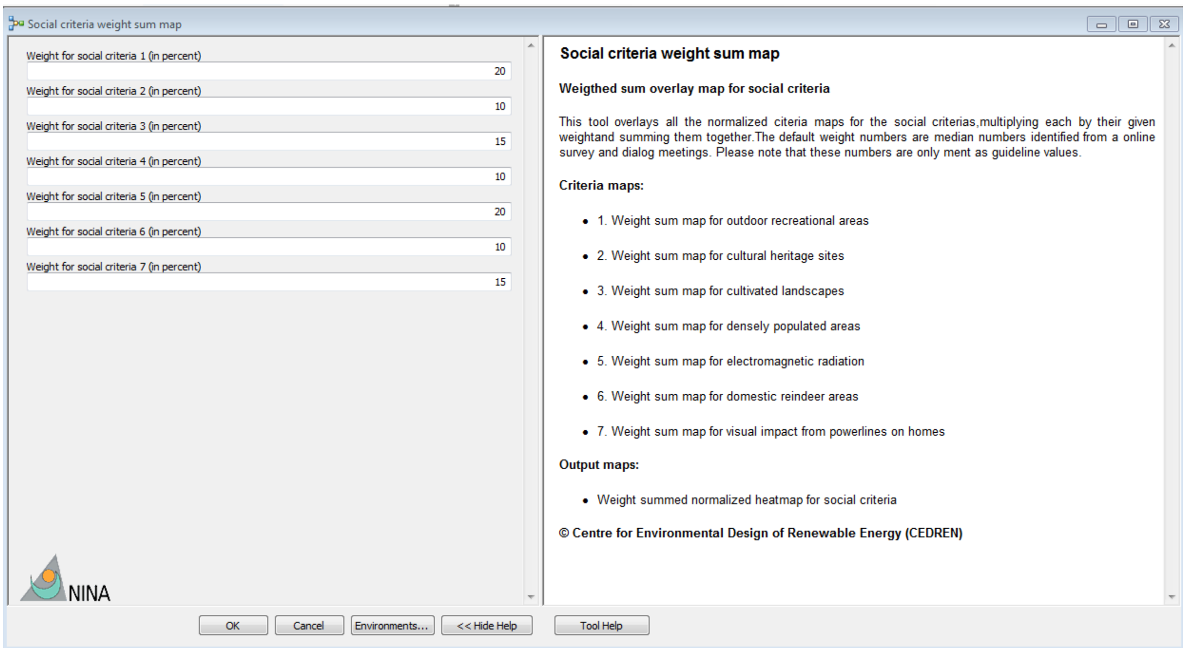


Figure 26. *Example: Weight-summarizing all social criteria maps*.

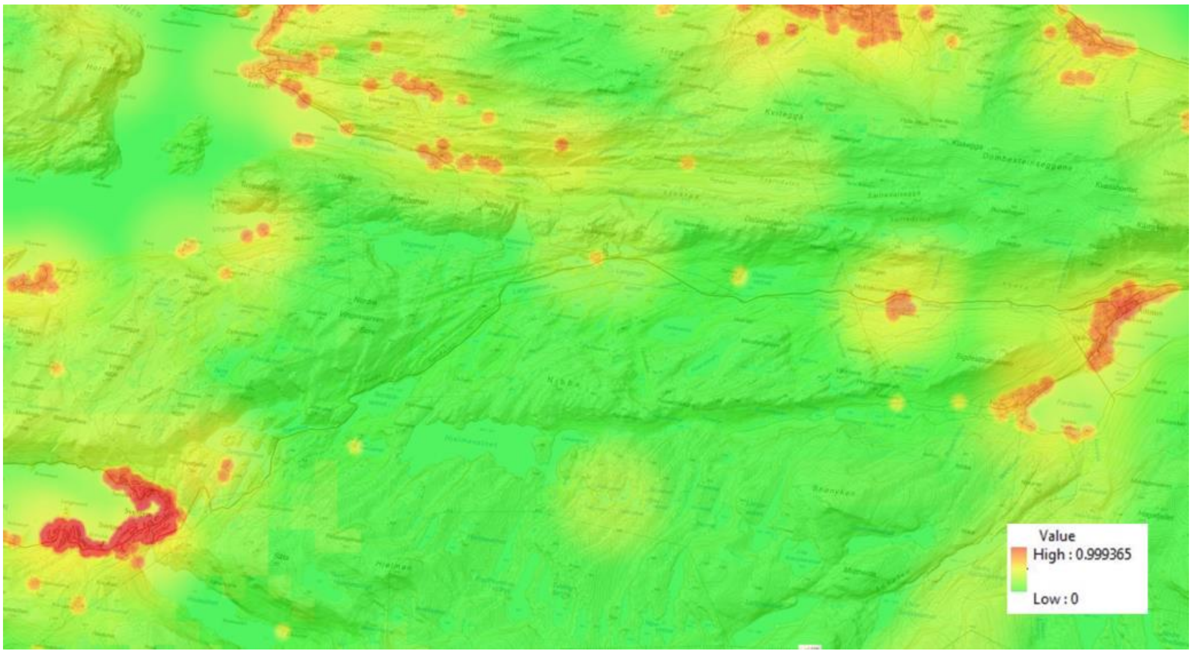


Figure 27. *Example: Aggregated map for Social criteria (Bremanger municipality in western Norway).*

6.3.2.5 Calculate Technological criteria maps

The next step is to calculate the Technological criteria maps (**Figure 28**). In principle, it is exactly the same process as described above (cf. **Figures 29-32** for illustrated examples).

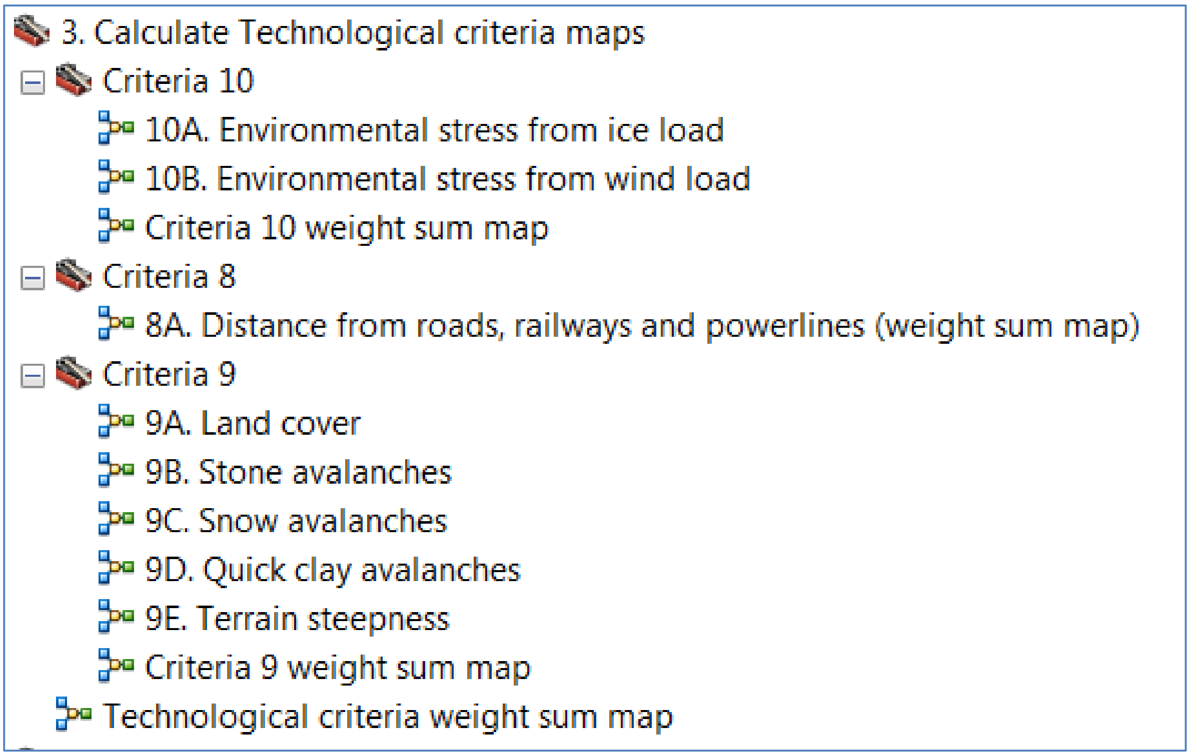


Figure 28. *Calculate Technological criteria maps.*

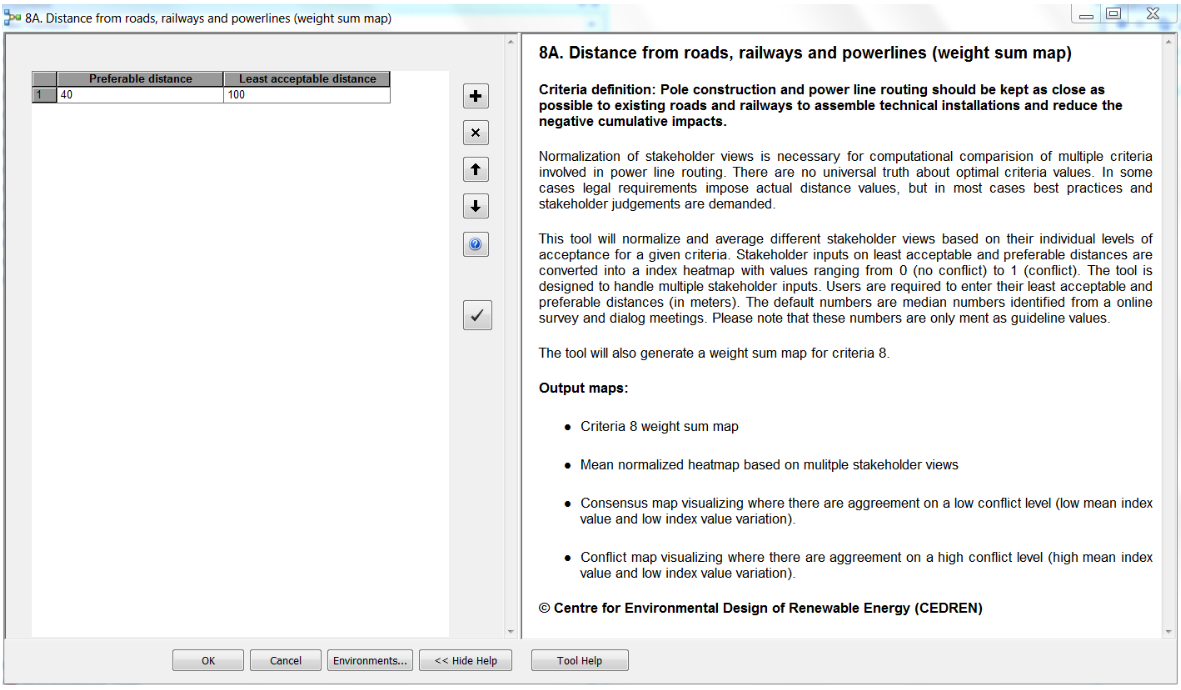


Figure 29. *Example: Weight sum map for criteria 8a: Distance from roads, railways and power lines. Pole construction and power line routing should be kept as close as possible to existing infrastructure to assemble technical installations and reduce negative cumulative impacts.*

Figure 30. *Example: Weight sum map for criteria 8a: Distance from roads, railways and power-lines (Bremanger municipality in western Norway).*

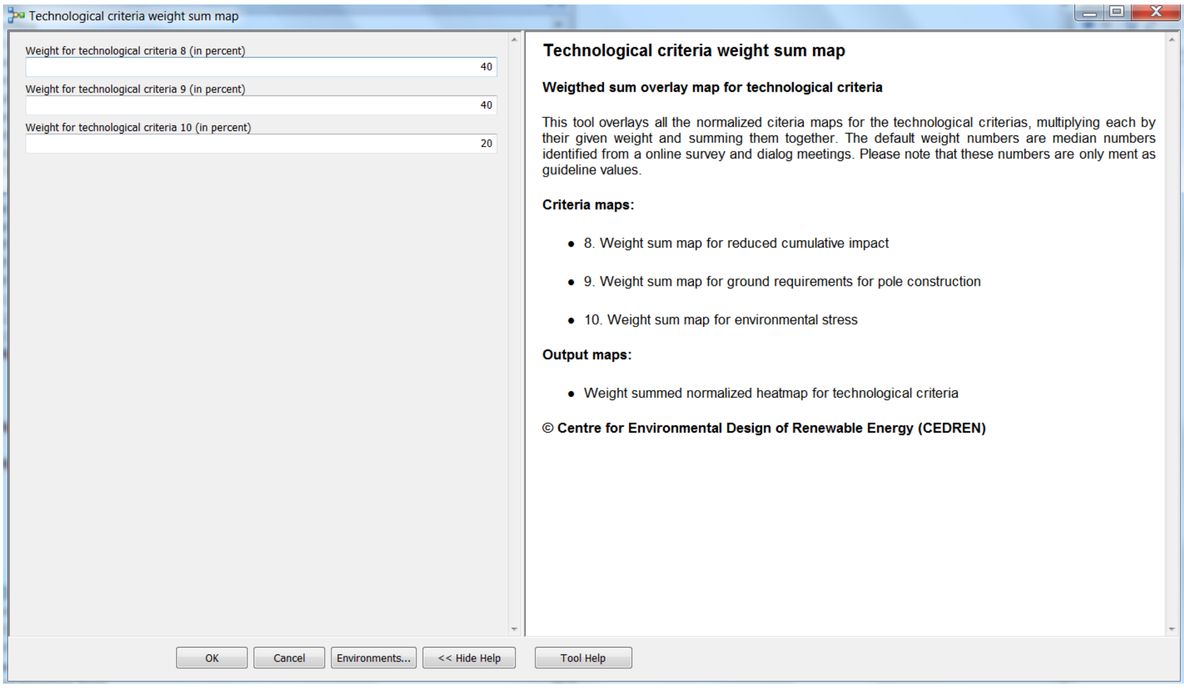


Figure 31. *Example: Weight-summarizing all technological criteria maps.*

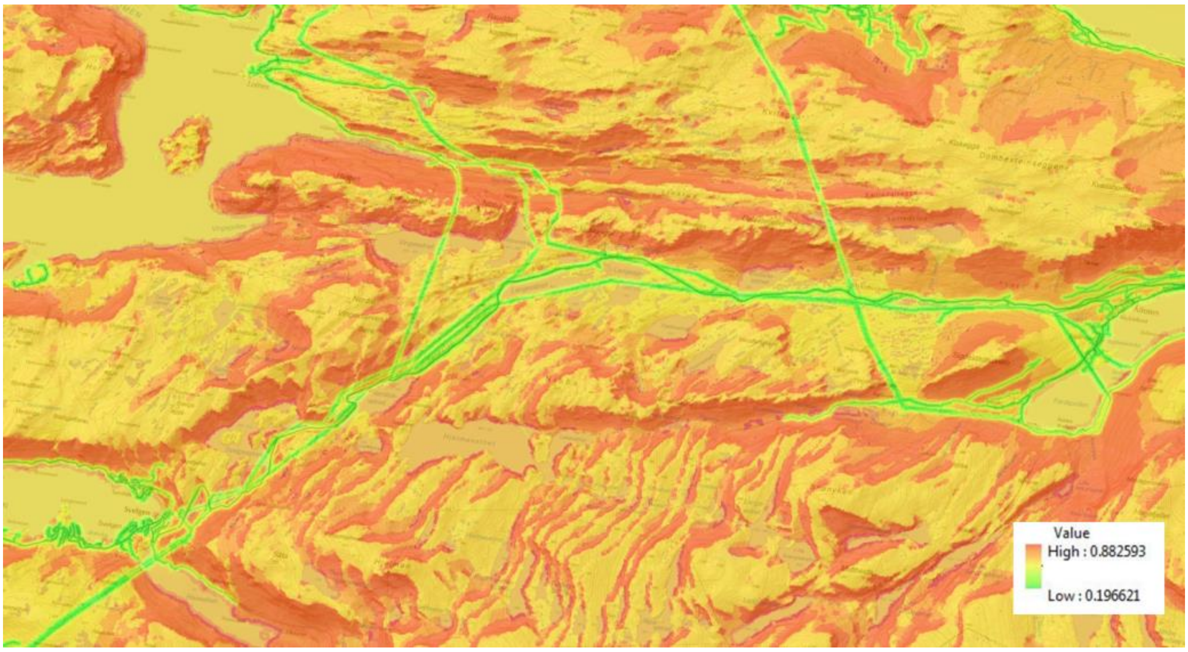


Figure 32. *Example: Aggregated map for Technological criteria (Bremanger municipality in western Norway).*

6.3.2.6 Calculate Ecological criteria maps

The next step is to calculate the Ecological criteria maps (**Figure 33**). In principle, it is exactly the same process as described above (cf. **Figures 34-37** for illustrated examples).

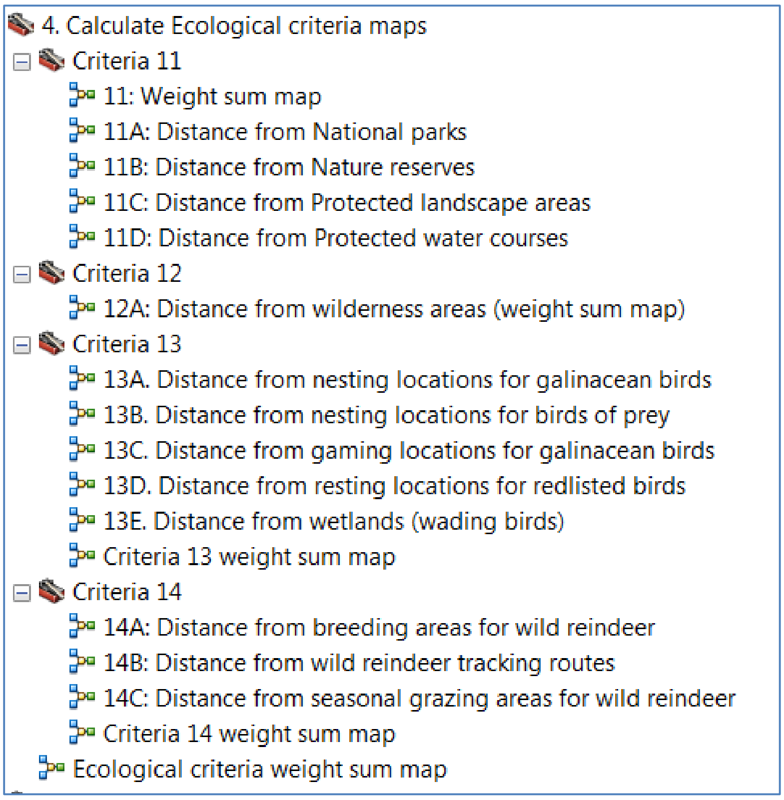


Figure 33. *Calculate Ecological criteria maps.*

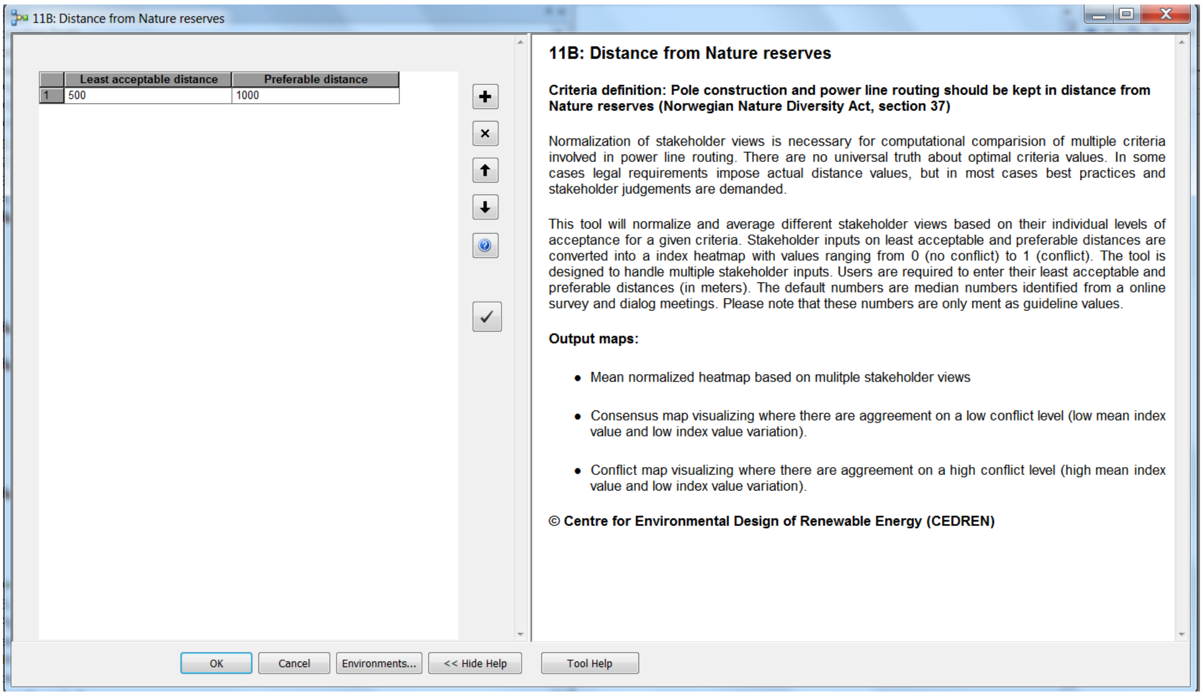


Figure 34. *Example: Calculate Distance from Nature reserves.*

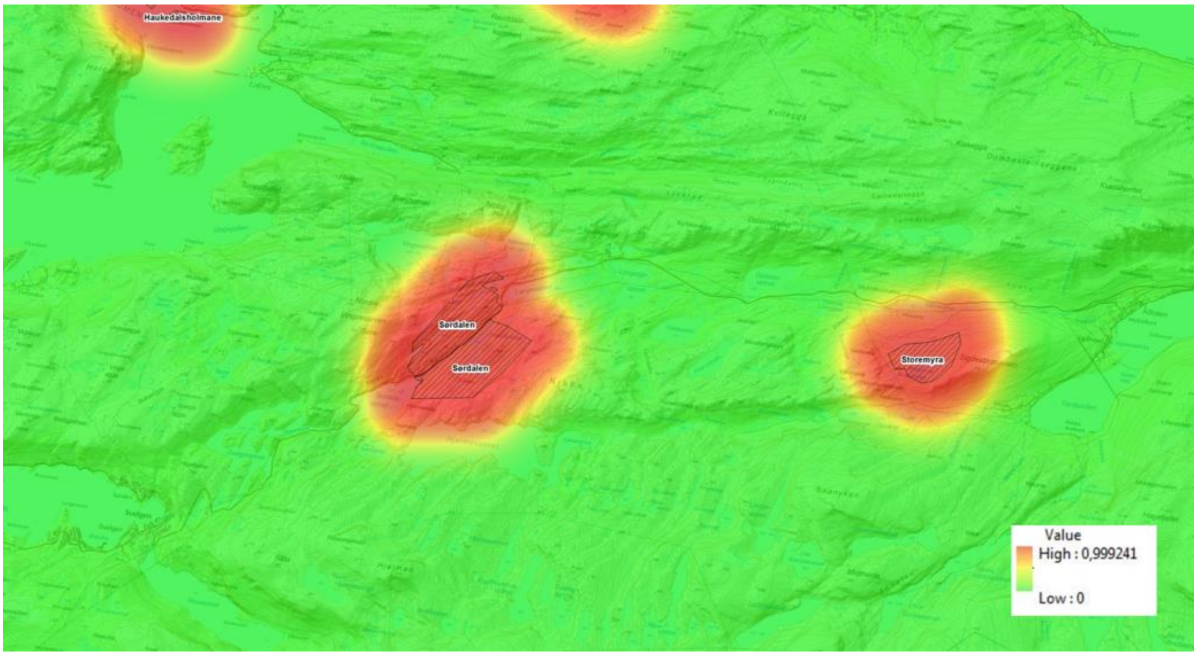


Figure 35. *Example: Distance from Nature reserves (Bremanger municipality in western Norway)*.

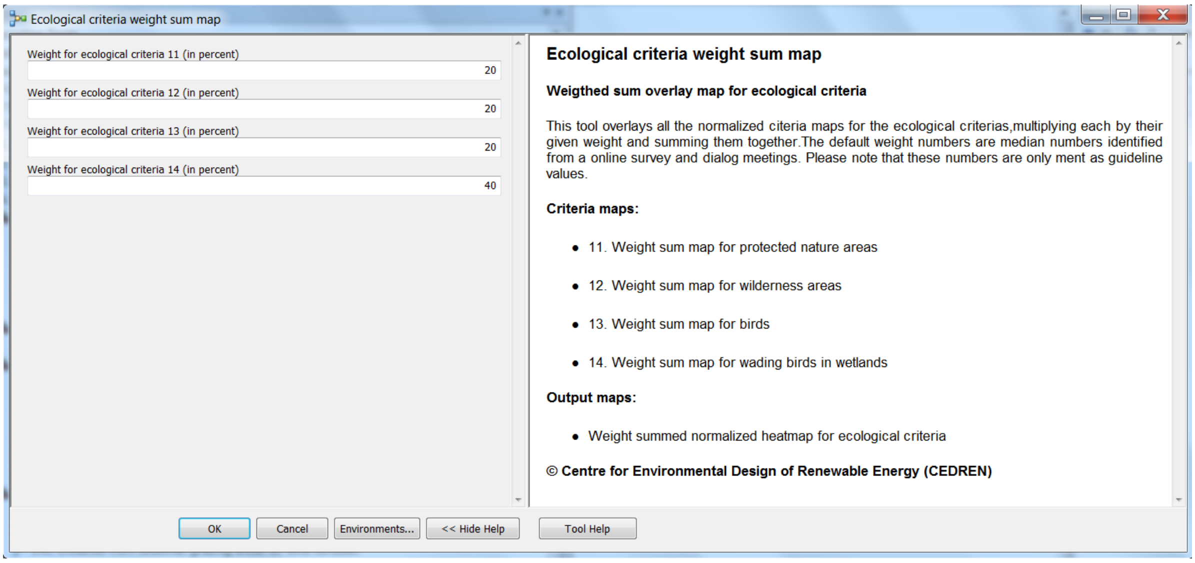


Figure 36. *Example: Weight-summarizing all ecological criteria maps.*

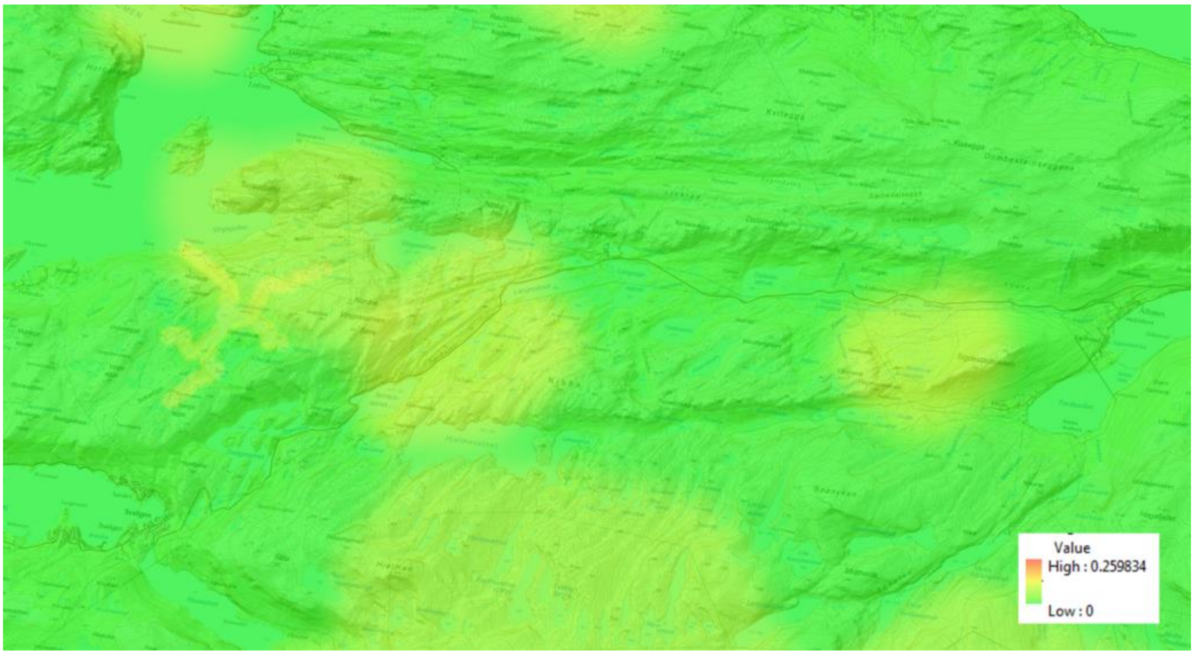


Figure 37. *Example: Aggregated map for Ecological criteria (Bremanger municipality in western Norway)*

6.3.2.7 Calculate routing maps

The next step is to calculate the routing maps (**Figure 38**) (cf. **Figures 39-40** for illustrated examples).

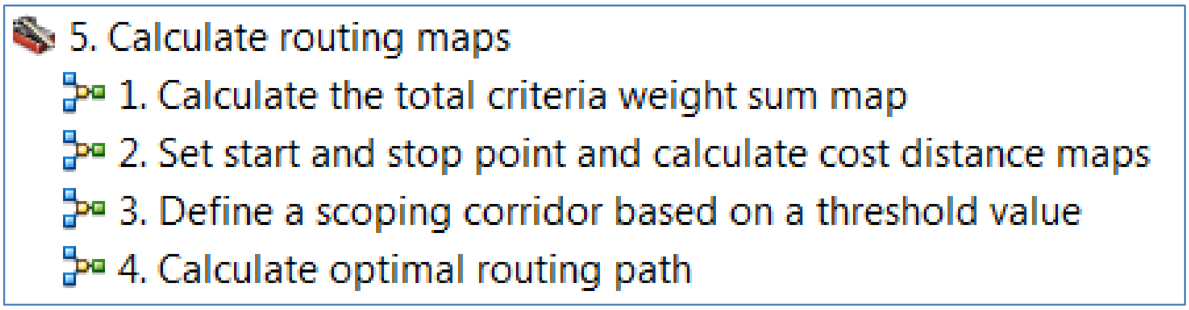


Figure 38. *Calculate routing maps*

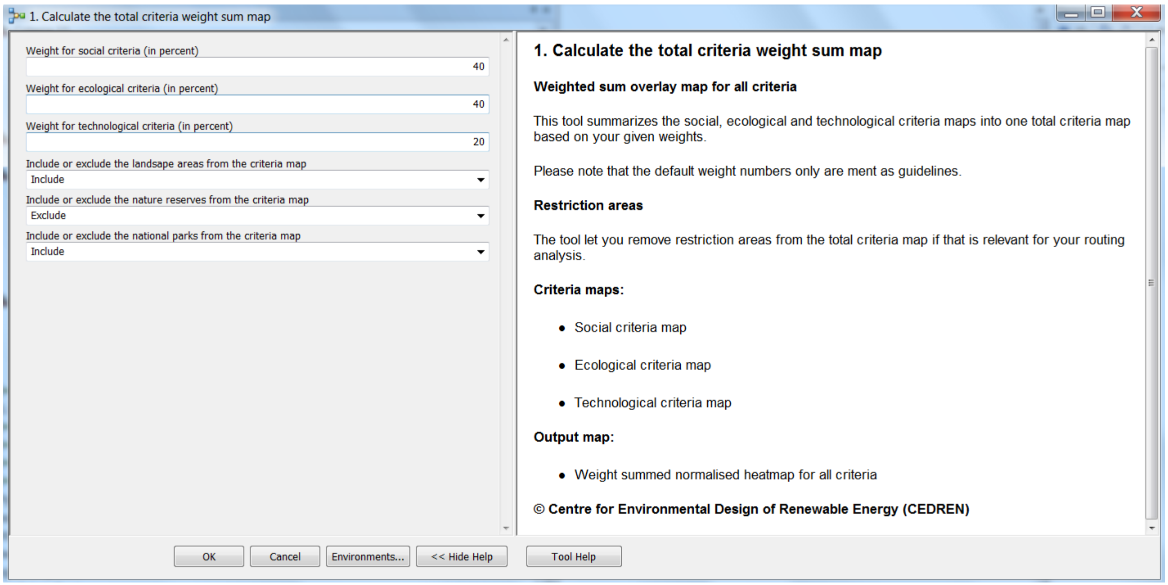


Figure 39. *Example: Weight-summarizing social, technological and ecological criteria maps into one map (using Nature reserves as a restriction area or "coockie-cutter").*

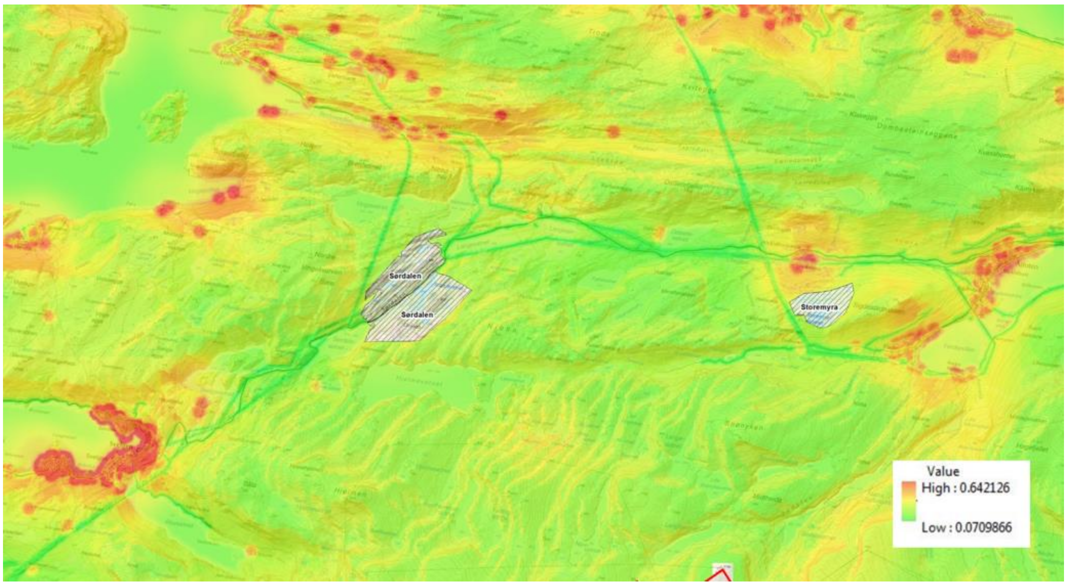


Figure 40. *Example: Total aggregated cost index surface for social, technological and ecological criteria (Bremanger municipality in western Norway). The Nature reserves are assigned as No-Data areas, meaning that no routing is allowed in these areas.*

To calculate the optimal path and corridor over the total cost index surface one has to indicate a start and stop location for the calculation. The toolbox will then start to calculate the least accumulative cost distance for each pixel to the nearest source over the total cost index surface (For a detailed explanation of how the cost distance are calculated visit http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//009z00000025000000.htm).

The output cost distance map has to be classified (e.g. by natural breaks or standard deviations) in order to visually determine a suitable threshold value for generation of a least cost corridor. **Figure 41** illustrates how a corridor can be determined using standard deviations.

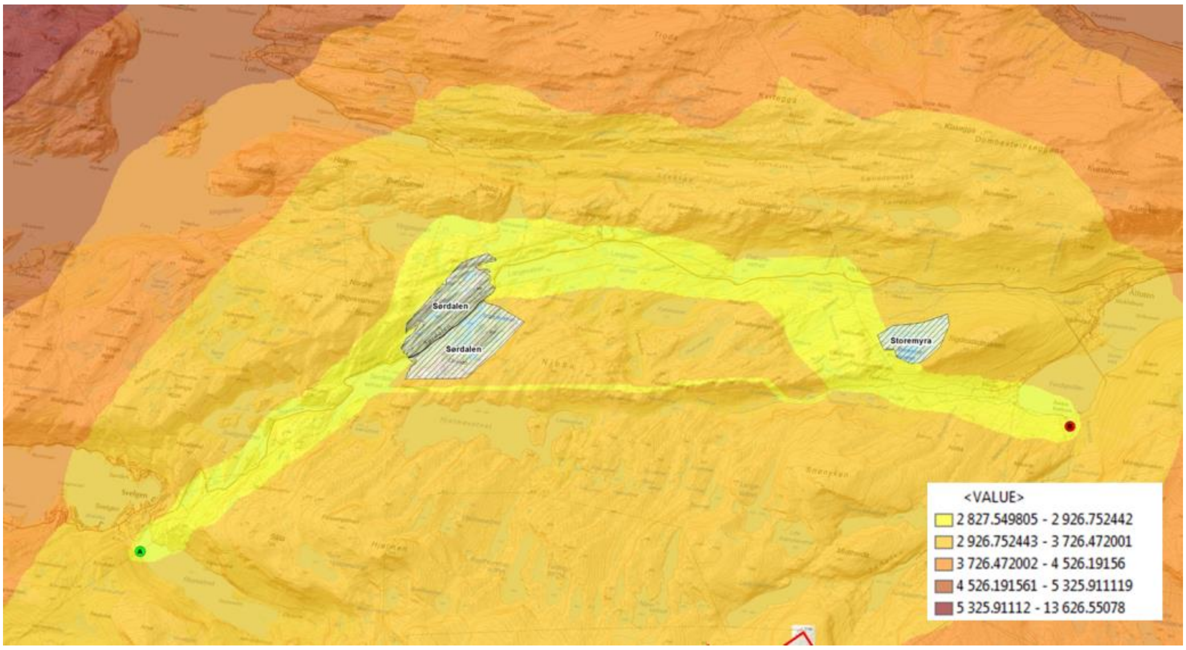


Figure 41. *Example: Classified cost distance map between the start (A) and the stop (B) location (Bremanger municipality in western Norway). The cost distance is classified using ¼ standard deviations.*

If decided to use e.g. a ¼ standard deviation as a threshold value for generation of a scoping corridor the corridor will include all pixels with cost distance values below 2926.75. Typing this threshold value into the “Define scoping corridor tool” will outline the scoping corridor (**Figure 42**).

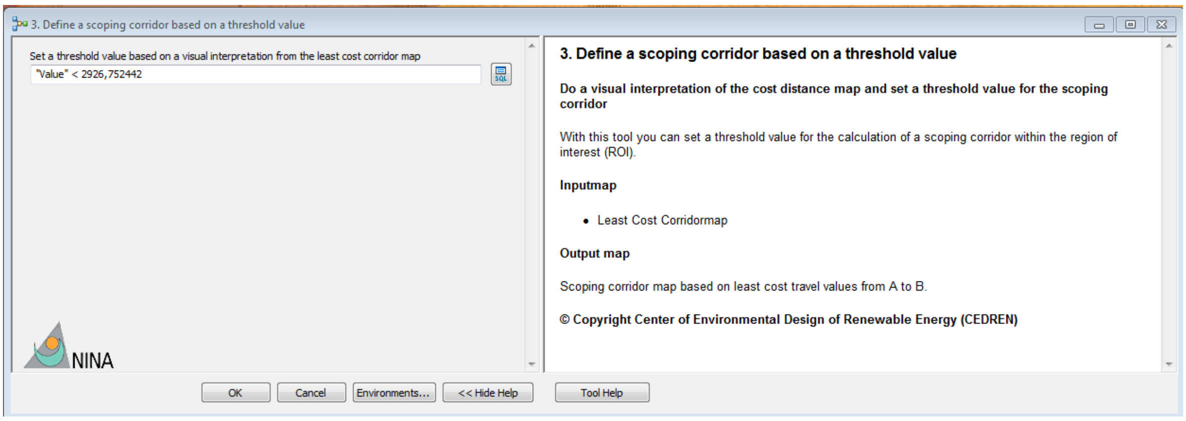


Figure 42. *Example: Scoping corridor calculation.*

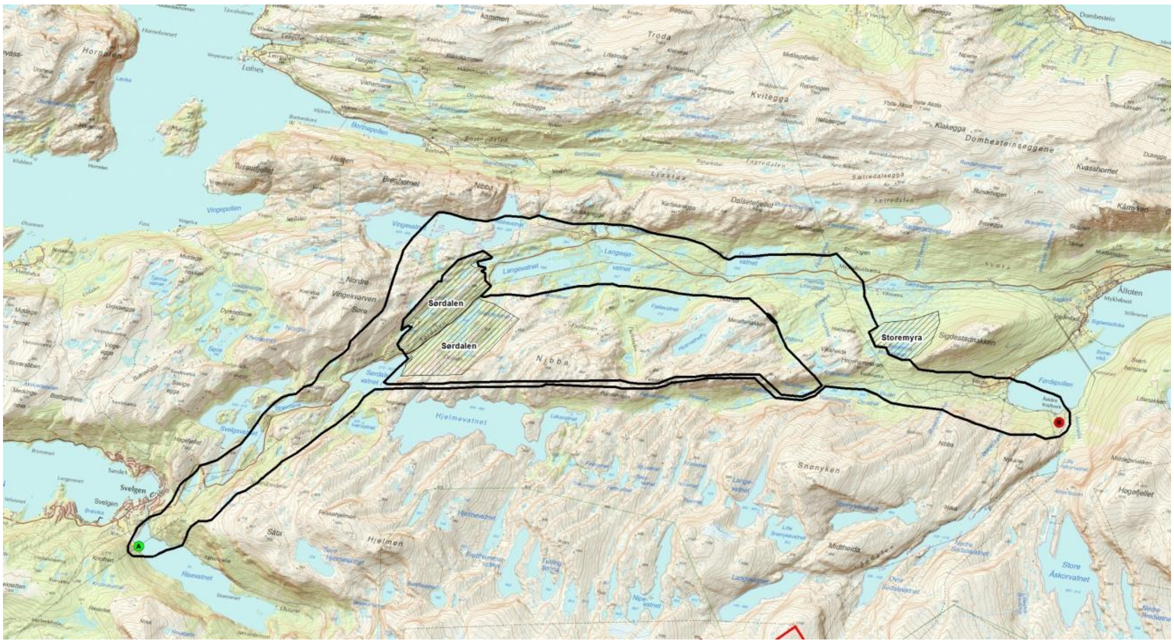


Figure 43. *Example: Scoping corridor generation (Bremanger municipality in western Norway).*

Finally also the least cost path can be calculated from the cost distance map. There are three algorithms for this purpose and they are all included into the toolbox:

- EACH_CELL: For each cell with valid values on the input destination data, a least-cost path is determined and saved on the output raster. With this option, each cell of the input destination data is treated separately, and a least-cost path is determined for each from cell.
- EACH_ZONE: For each zone on the input destination data, a least-cost path is determined and saved on the output raster. With this option, the least-cost path for each zone begins at the cell with the lowest cost distance weighting in the zone.
- BEST_SINGLE: For all cells on the input destination data, the least-cost path is derived from the cell with the minimum of the least-cost paths to source cells.

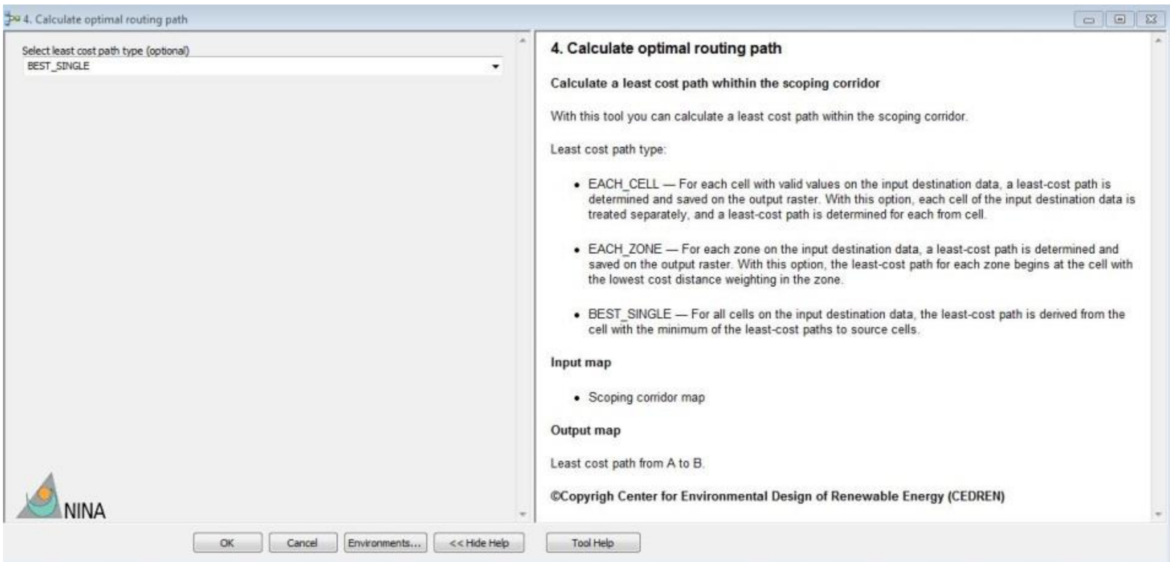


Figure 44. *Example: Least cost path calculation.*

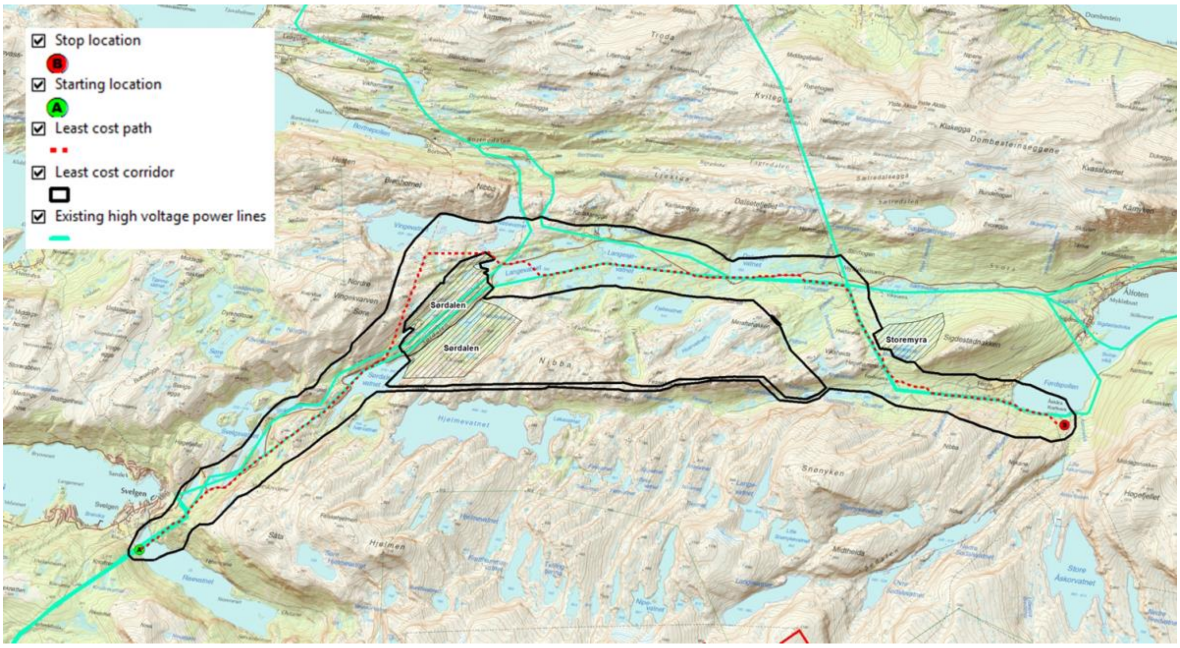


Figure 45. *Example: Least cost path and corridor outside the protected Nature reserves (Bremanger municipality, western Norway).*

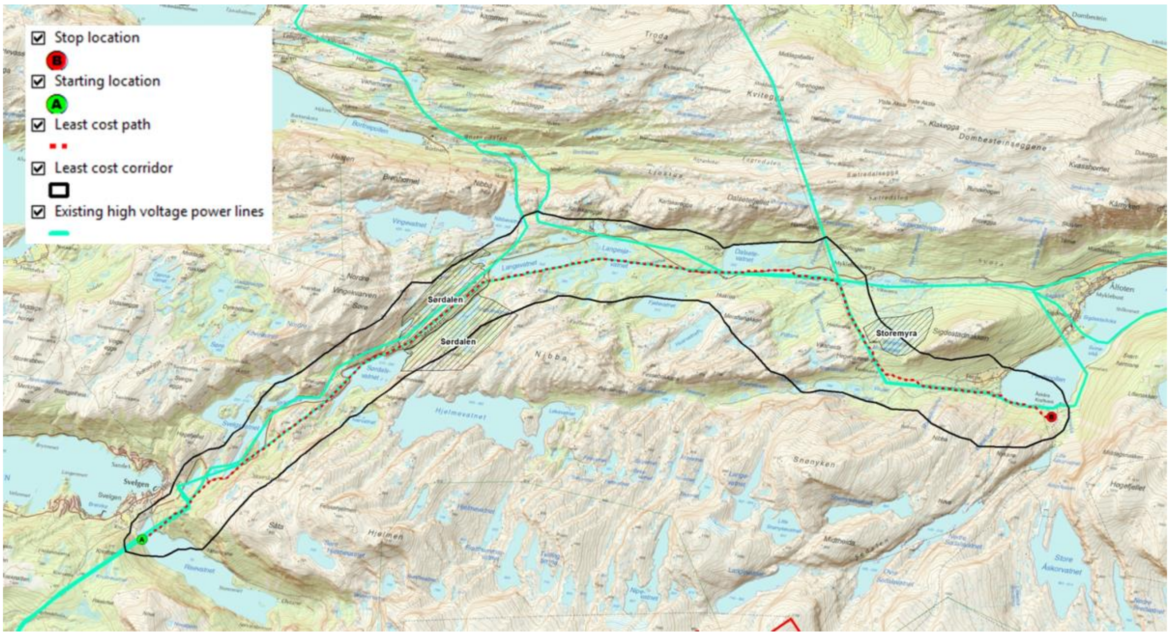


Figure 46. *Example: Least cost path and corridor inside the protected Nature reserves (Bremanger municipality in western Norway).*

The calculated least cost path in **Figure 44** correlates spatially relatively well with the existing 132 kV transmission line. Since the Nature reserve were excluded from the calculation as a restriction area the modelled line mainly deviates from the existing line only outside the protected Nature reserve.

The actual nature reserve is currently (as illustrated in the map) divided in two parts by a road and a 132 kV transmission line. If we allow the routing to go through the Nature reserve (**Figure 46**) the spatial correlation yields a nearly perfect match with the existing 132 kV transmission line. This local example shows that the current power line routing practice and the OPTIPOL LCP Toolbox give very similar results, hence supporting each other.

6.4 Conclusion and further progress

The LCP toolbox could be a very helpful planning tool when applied at an early planning phase in order to scope environmental impact assessment, reduce potential stakeholder conflicts and to make the decision process more transparent to the public. In their power-line project cycle, Statnett consider OPTIPOL LCP to be a useful tool during the initial feasibility study and the public inquiry phase prior to the governmental designed impact assessment program.

The CEDREN-project SUSGRID (Sustainable grid-development) have compared the common grid development practice in Norway with Sweden and UK (Brekke & Sataøen 2012). According to their conclusions, there are virtually non-existing political guidelines on grid development in Norway. The planning and decision-making system is described as purely expert-oriented, with a predominant focus on transmission grid production safety. The Norwegian planning and decision system is also considered to have insufficient links between all levels of grid planning. All these constraints in turn create problems with public acceptance and political legitimacy, and could make it more difficult to convince the general public of the importance of the major focus on transmission grid production safety in itself. SUSGRID emphasizes the need to see the overall context. We consider that this is ensured through OPTIPOL LCP because of its user driven approach, its flexibility and its open verification ability (see http://www.cedren.no/Projects/SusGrid.aspx).

The OPTIPOL LCP Toolbox has been widely presented at international conferences on impact assessment, societal impacts of improved environment, and power-line right-of-way management and geospatial technology. Feedbacks from among others the EU Commision (DGE Environment) has underlined particularly the potential of the OPTIPOL LCP tool as an important contribution to holistic decision making, democratization, user participation and increased efficiency in connection to huge development processes. Great interest have also been expressed regarding implementation of the OPTIPOL LCP methodology from STATOIL (routing of offshore pipelines), The European Incoherent Scatter Scientific Association- EISCAT (siting of new radar facilities in northern Scandinavia) and the County council of South Trøndelag (land use planning and siting of windpower plants).

The LCP methodology will be further developed and adapted to least cost siting (LCS) as a part of the CEDREN Common Activities (2014-2016). In addition NINA and a wide range of international partners have now implemented the OPTIPOL LCP results in several research applications focusing on siting of fish farms (Horizon 2020) and siting of wind energy (European Economic Area Grants for Czech Republic, Romania and Lithuania).

OPTIPOL LCP 2.0 is based on standard ESRI technology being directly compatible with the ESRI ArcGIS Server Platform. To further develop and test the method, the tool and the criteria used, it is important to find a cooperating partner. The project cooperation should focus on technology and methodology development and processes connected to increased user participation (cf. conclusions from SUSGRID and Rokkansentret).

A big grid owner company like e.g. Statnett would have the best qualifications to identify a case for a possible cooperation project e.g. in connection to the development of the Central Grid. It is also important to have an estimate of possibly increased efficiency and return of investments by using the toolbox.

The OPTIPOL LCP Toolbox 2.0 was presented at the final user meeting in Trondheim February 4.The response from the Norwegian Water Resources and Energy Directorate, Statnett and the Norwegian Environment Agency was positive. Statnett will do major investments in upgrading/new construction of the central Norwegian grid in the coming 10 years. This will demand more stakeholder involvement, more effective planning tools and new mitigation measures in order to reduce potential stakeholder conflicts and find the optimal solutions. The discussions at the end of the meeting revealed several focal areas for new project development in the interface between user needs and scientific opportunities.

7 Power-line camouflaging, bird mortality mitigation, technical implications

7.1 Background

In their "Letter of intent" (2008), when NINA applied for OPTIPOL funding to the Research Council of Norway, NVE stressed that "*NVE has recently finalized an evaluation of power-line camouflaging as a measure to mitigate landscape impacts. However, we have not focused on possible impacts on birds and would like to have an improved knowledge basement to assess how camouflaging may impact bird collision risk with power lines."* Thus, in the final OPTIPOL design a specific work package was dedicated power line camouflaging – to assess both possible ecological and technical impacts.

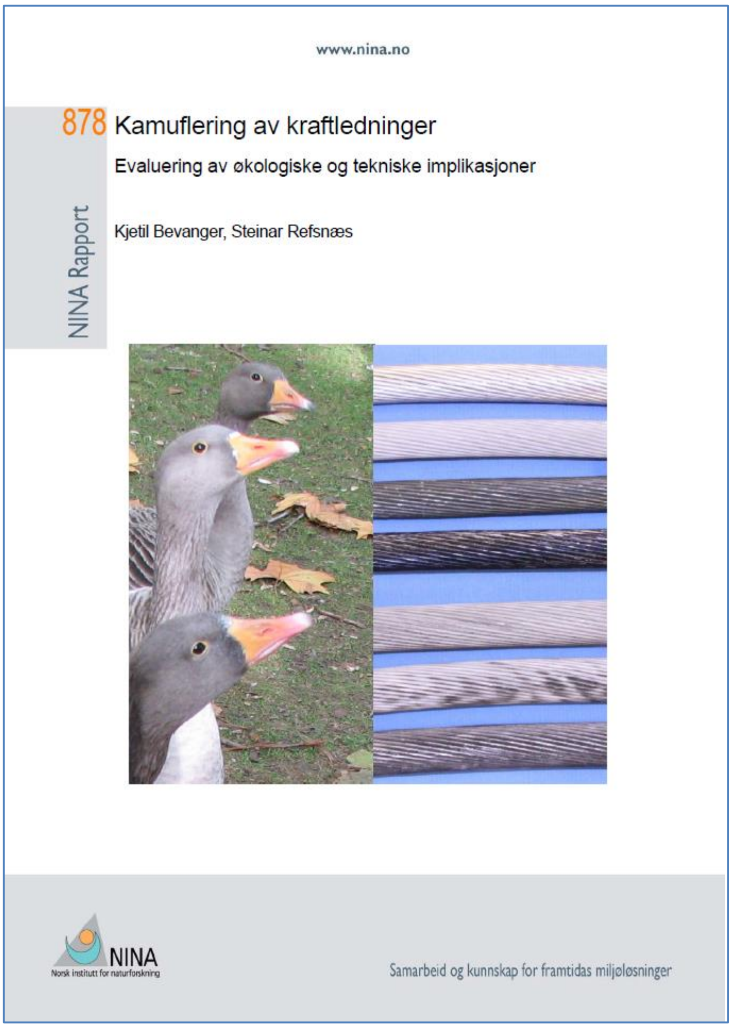


Figure 47. *A "State-of-the art" report on ecological and technical implication of power-line camouflaging" is published by NINA and CEDREN (Bevanger & Refsnæs 2013a)*.

NINA Report 878 – "*Power line camouflaging. Assessments of ecological and technical implications"* (**Figure 47**) is summarizing the state of the art, and here we only refer the report summary and conclusions. Whether use of colours and other cues modifying the visual impression of power line structures, i.e. camouflaging them, reduces or increases the risk of bird collision, has not been subject to specific evaluation in Norway since 1999. Largely, this also applies to technical aspects of camouflaging cues. The NINA Report 878 is summarizing what is known on bird vision and behavioural aspects as a background for a more thorough discussion about whether camouflaging power lines and power-line structures to make them as invisible to the human eye as possible, might increase the susceptibility for birds to collide with them. From an "avian perspective" the aim would be to make power lines as visible as possible to the birds.

7.1.1 Results and conclusions

7.1.1.1 Ecological aspects

The mammalian and bird eyes have many common features, and anatomy and function is relatively well studied and understood. It appears, however, that it is incorrect to assume that different species perceive their environments in the same way. With respect to bird colour vision, depth vision and vision acuity, there are several unanswered questions when it comes to power-line camouflaging. For birds to achieve an optimal detection of a power line, it is important to optimize the contrast of the line against the background colour. Several scientists assume that some bird species have an advanced ability to separate colours in the yellow part of the light spectre. It seems likely that some green and yellow colours, particularly if these at the same time have an UV contribution, contrasts against a natural green background. To reduce the contrast between an air wire and the background, e.g. by matting the blank surface of a FeAl-wire with a black or a grey-blackish colour, will probably increase the collision risk for some bird species. To make the conductors and earth wires as visible as possible from an avian perspective, in general it seems best to localise power lines in a way that optimizes the contrast against the background. The seasonal variations in Norway make an environmental colour cycle – from white in the winter through brownish-black in the spring to green in summer and yellow-red in the autumn. Thus, regardless of camouflaging colour used, there will be periods when the power lines will be quite visible (Bevanger & Refsnæs 2013a).

7.1.1.2 Technical aspects

In exposed coastal areas there is a high risk of crevice corrosion beneath a poor adhesive coating. Coating applied after the group of wires has been spun around the central core has a tendency to hamper drainage in the line. Thus, the coating promotes internal corrosion between the filaments and the filament layers, particularly on the lines lowest point. Matted or primed camouflaged power lines seem to do well in coastal environments with low corrosiveness. The emission factor $\boldsymbol{\varepsilon}$ is dependant of the surface structure of the line. By increasing the emission factor, the cooling effect can be increased due to emitted heat, and the capacity of current transfer is increased by approximately 5 %. An isolating coating on the camouflaged line can result in contact problems and breakdown, and must be considered during installation and selection of binding posts. Immediately prior to installation of clamps and splices, the contact surfaces must be treated with e.g. a steel brush or emery cloth. Apart from that, a thin layer of grease should be applied to the contact surfaces. This will reduce the oxide growth and seal the contact areas against water penetration and pollution which can induce corrosion (Bevanger & Refsnæs 2013a).

7.2 Mitigating bird mortality

7.2.1 Background

One of the topics NVE, being one of the OPTIPOL User Group Members expressed their interest in was an evaluation of the effectiveness of commonly used bird mortality mitigating devices. Mitigating measures to reduce bird mortality due to utility structures has been an important research topic for several years because of the economic impact outages caused by these incidences may have, as well as the biological and species-specific consequences of this additional mortality among birds. The final OPTIPOL design consequently included a specific work package dedicated both possible ecological and technical issues. A NINA Report – "*Possibiliteis and constraints in reducing bird collisions and electrocution in the existing power-line grid in Norway"* (**Figure 48**) (Bevanger & Refsnæs 2013b) summarizes the state of the art, and here we only refer the report summary and conclusions.

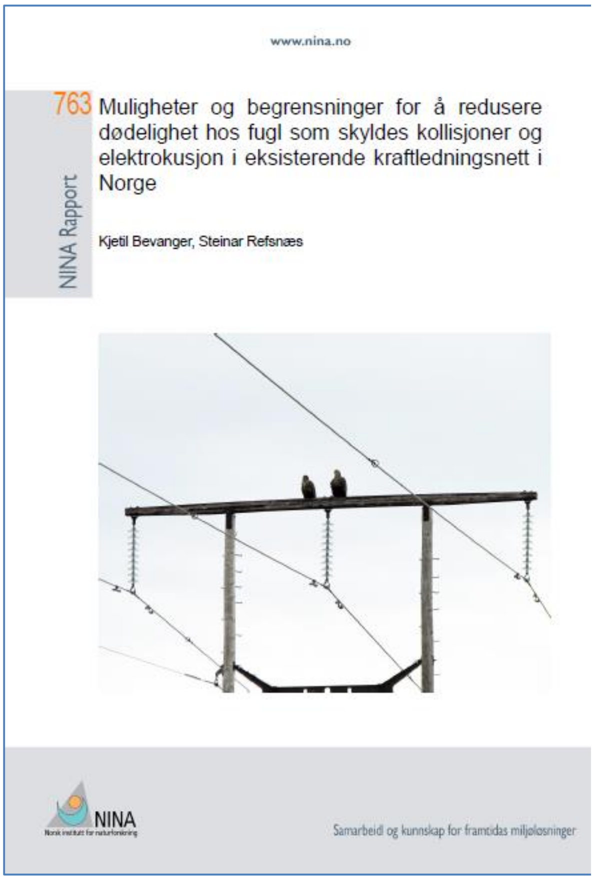


Figure 48. *A "State-of-the art" report on "Possibiliteis and constraints in reducing bird collisions and electrocution in the existing power-line grid in Norway" is published by NINA and CEDREN* (Bevanger & Refsnæs 2013b).

7.2.2 Results and conclusions

7.2.2.1 Ecological aspects

Bird collisions with power lines and electrocution are strongly species-, site- and seasonal-specific accidents. It is important that future research becomes more site- and species-specific when approaching these problems and that the mitigating measures are based on facts: 1) what are the target species. i.e. which one are the most vulnerable; 2) what is the best design when it comes to marking devices to reduces the collision frequencies among the target species; 3) what are the success rate or likelihood to reduce the mortality of the target species when it comes to economic investment of power-line marking? Such knowledge will make it easier to argue for the importance of mitigating measures, be it environmentally or monetarily. Knowledge on population consequences of the additional mortality due to utility structures is more or less none existing, and will be a particularly important topic to address for future research.

Physical enlargement of the phase conductors or ground wires using some sort of marking devices has proved to reduce the collision frequencies for some species. Making wire marking as a routine when new power lines are constructed, could be an issue in areas with known collision hot spots, in areas with high bird densities (e.g. wetlands) and when crossing typical leading lines (e.g. rivers, narrow valleys and straits). It could also apply to power lines crossing local migrating routes between resource areas (e.g. nesting localities and feeding grounds), and in areas with high densities of diurnal species known to be vulnerable to collide (e.g. swans and cranes).

To increase the knowledge on where and when power-line marking should be implemented, more data on species- and site-specific collision risk as well as species-specific behavioural responses are needed relative to different marking cues. For some species, there will probably be no solutions at all («no cure species») except for earth cabling. A long dusk period and a short period with light during the day, like in northern Europe and Norway during the winter (close to six months), offer minor possibilities to reduce the mortality among e.g. gallinaceous birds, being birds particularly vulnerable to collide with artificial air obstacles.

The report (Bevanger & Refsnæs 2013b) focuses on the possibilities to act in connection to the exiting grid, thus discussions on optimal routing of a power line through the terrain and options that only can be considered during the construction of a new power line are omitted. There is, however, no doubt that the best mitigation and precocious steps to prevent birds from colliding with power lines are connected to an optimal routing.

Bird electrocution is mainly connected to utility structures within the grid systems below 66 kV, and the knowledge on what type of technical devices that are the most frequent electrocuting traps is substantial. However, the diversity with respect to technical design within the distribution grid, as well as limited national and international standards is a challenge when it comes to implement and transfer knowledge from one place to another. The predictability is nevertheless high with respect to what type of devices, structures and design makes an electrocuting trap for birds. Recommendations given 25 years ago is followed up neither by the energy authorities nor the grid owners, and a main reason to a high number of electrocution accidents among birds in Norway is because well-known technology and solutions is not implemented.

Cost-effective actions to reduce electrocution accidents among birds must be based on field data. This has been underscored also among scientists in both the US and several European countries. Unfortunately there are few Norwegian studies when it comes to concrete information on bird electrocution, thus it is an urgent need for research that can come up with systematic information on what species that are most frequently electrocuted in space and time, i.e. in different parts of the country – when – and in connection to what structures. The Norwegian knowledge is mainly anecdotal and based on accidental observations of dead, electrocuted birds. A recent study on the Smøla Island, off the coast of Central Norway, confirmed that only a tiny number of the power-line poles represented a high electrocution risk. Over 50 % of more than 200 electrocuted birds recorded in connection to approximately 740 poles predicted to pose an electrocution risk in the 22 kV grid, was connected to 2.8 % (21) of the poles (Bevanger et al. 2014).

7.2.2.2 Technical aspects

Several Norwegian grid companies are logging anomalies in their grid systems rather frequently due to bird electrocution. The annual statistic recordings for incidences, interruptions in energy delivery and errors in the 1-22 kV grid for 2008, confirm that birds (together with a few incidences where squirrel and marten have been involved) are responsible for 13 % of all anomalies and 3 % of "not delivered energy". Average number of anomalies due to birds seems to be 8-10 times higher along the coastline compared to inland areas, however, with significant local variations within the coastal distribution grid areas. Consequently, it is important, also from the grid owner's point of view, to take actions to reduce the disruptions in stable electricity delivery caused by birds. It is, however, important that the actions taken do not violate the security of supply in the grid systems. The present report points at some particularly important issues that should be kept in mind.

Insulated metallic crossarms protects against bird electrocution as well as reduces short outages in grids lacking a Peterson coil earthed system. The negative side is increased corrosion possibilities and lack of disengagement if the phase conductor falls down on the crossarm. Installing a bird protection system on the arching horn may also reduce the number of short outages due to earth-fault currents.

A modified "eagle owl crossarm" (Bevanger et al. 2011) protects against interruptions in the energy supply due to the short-circuit or earth circuit made by the bird. In inland areas a plastic cover on the phase conductors may be deployed without risking damage due to corrosion, however in exposed coastal areas this can imply increased local corrosion and risk of wire fatigue fracture (Bevanger et al 2014).

Bird flight diverters and other types of spirals commonly used to make the wires more visible to birds may reduce the number of interruptions in the energy supply in the grid due to heavy birds, like swans, colliding with the phase conductors and dragging them together. However, these devices may also create a greater windage or windsail, icing problems in highland areas and possibly increased wear and tear in the wire suspension area. Spirals may however, reduce vibrations and thus the risk of fatigue in the suspension point. So far, there are no indications of these devices contributing to wear and tear or corrosion of the wire itself.

Removal of earth wires, either being located above or below the conductors on power lines up to 24 kV, and locating the earth wire on the underside of the crossarm, may result in a significant higher number of damages to the customers due to lightening in the vicinities or induced overtensions in the grid. Use of Peterson coil earthed systems, requirement for a minimum time of disengagement and use of continuous earth wires in the aerial grid, are the most important actions taken to minimize the consequences of unintended earth-fault situations in the high-tension grid. The likelihood of pole fires in the 12-24 kV grids seems to be at its maximum in coastal areas with 25-35 year old systems lacking a continuous earth wire. With bonding of the metallic parts in the power-line pole top and earth conductors, the earth connection usually drains the residual current in a way that high current densities in the wooden parts is avoided.

Straight-across mounting can probably reduce the bird collision frequencies significantly; however, a flat line configuration depends on larger distances between the phase conductors and consequently a larger land area cession and more bush clearing in forest areas than a power line with triangular or vertical mounting. Earth, aerial insulated or submarine cables may have a lover cutoff frequency than an aerial power line in some areas, however, if a fault occurs the repair time is significantly longer for a cable system compared to aerial systems. A grid system including sections switching between cable and aerial wires can be a bad and vulnerable choice. Cable poles will increase problems connected to operational stability and maintenance and may increase the bird electrocution frequency. A majority of faults connected to cable systems occur in the cable-end pylons at the transition from an air to a cable system. Splitting with inserted cable sections may also be perceived as an "untidy" visual picture from an aesthetic point of view.

7.2.3 Design modifications to reduce eagle owl electrocution

Population impacts of bird mortality caused by electrocution in Norway is unknown, except for the eagle owl, for which electrocution accidents could have population impact (Bevanger & Overskaug 1998). Of 188 banded eagle owls recovered in Norway, 68 (36%) were killed by power lines (electrocution or collision) (Bakken et al. 2006). The most dangerous structures are pole mounted transformers and poles with cable debranching at power lines with 22 kV-132 kV (Bevanger & Thingstad 1988). Before releasing captive bred eagle owls in the county of Østfold in 1987, some dangerous power lines were insulated. While 4 of 10 released birds with radio transmitters were killed in 1986, only 1 of 8 individuals were killed in the same area after mitigating actions (insulation of dangerous structures in connection to pole mounted transformers) (Larsen & Stensrud 1988).

Covers installed over the insulators and conductors are generally the preferred method for retrofitting 22 kV overhead lines with pin-type insulators, to avoid electrocution. However, concerns regarding corrosion have been raised for such systems in exposed marine environments along the Norwegian coastline. In order to clarify the degradation rate of the conductors, estimate the life expectancy and to work out guidelines where the phase covers may, or should not be installed, accelerated corrosion tests have been carried out on five electrocution prevention insulation systems (Refsnæs et al. 2013). The corrosion tests simulated 12 years of exposure in two different marine corrosion environments. The conclusion from these tests is that covers installed over the insulators can be used in inland areas with very low corrosivity. Covers should not be installed in exposed coastal areas with a high corrosivity. The life expectancy of the conductors in these coastal locations is approximately 10 years (Bevanger et al. 2011, Refsnæs et al. 2013, Bevanger et al. 2014).

The OPTIPOL project initiated studies to develop technical solutions to reduce the electrocution-induced eagle owl mortality, not using conventional insulating methods. Due to the fact that the main eagle owl populations today is to be found in coastal areas with a high salinity in the air, and thus high marine corrosivity index, it was necessary to look for other solutions than traditional insulating measures of the conductors and other exposed metallic components. The possibilities for corrosion problems and outages are significant if metallic components are encapsulated allowing air and moist to act together over time.

In co-operation with the company El-tjenester AS, CEDREN (NINA and SINTEF) developed a modified pin insulators crossarm frequently used in the majority of the 22 kV grid. The crossarm is an attractive perching place for the eagle owl. The crossarm was prolonged on both sides and the prolonged parts were made higher than the rest of the crossarm, and the ordinary part was equipped with plastic cover with sharp spikes to deter the birds from using it.

The elevated perches and anti-perch devices (plastic bird spikes, Bird-B-Gone) were tested on 12 poles in three different eagle owl territories on Solværøyene in October-December 2011. The poles were monitored by Reconyx high performance wildlife cameras. The cameras were deployed 21 days before the elevated perches and plastic bird spikes were mounted, and took photos for 38 days after the deployment.

A total of 83.893 photos were taken. Most of them showed no birds. The cameras were frequently triggered by moving clouds in day-time and probably by heat from the conductors at night, giving false positive recordings. The eagle owl landed on elevated perches 26 times. There was no landing on crossarms with spikes (**Figures 49-51**). The construction proved to work, illustrating the importance of being species- and site-specific in the design approach when it comes to mitigating measures (Bevanger et al. 2014).

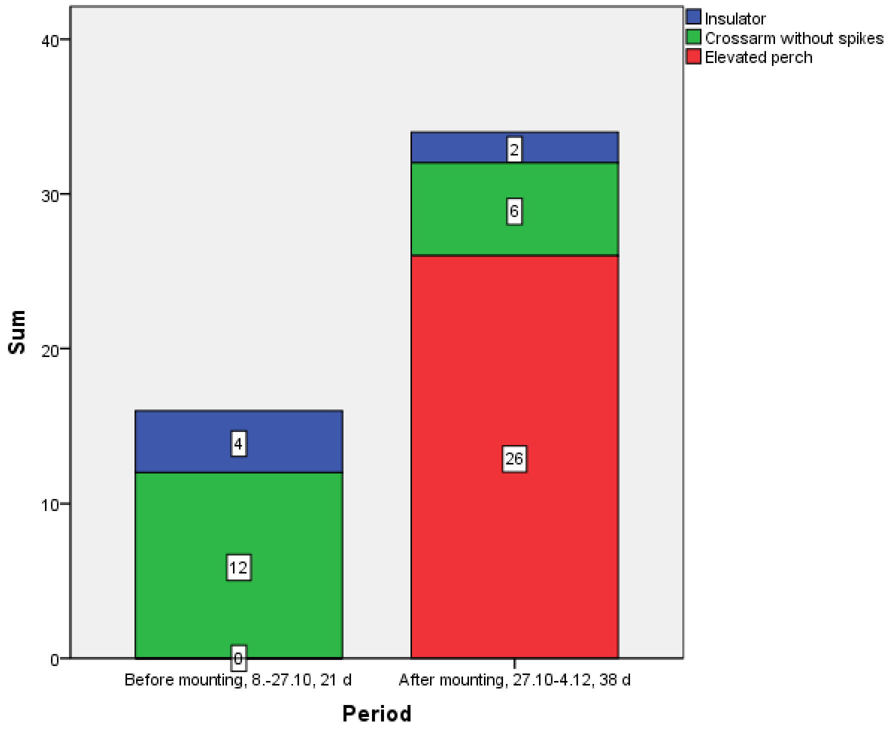


Figure 49. *Eagle owl landings on power-line pole crossarms without spikes, modified crossarm (with elevated perches and anti-perch devices) and pin insulators. After Gjershaug et al. (in print.)*

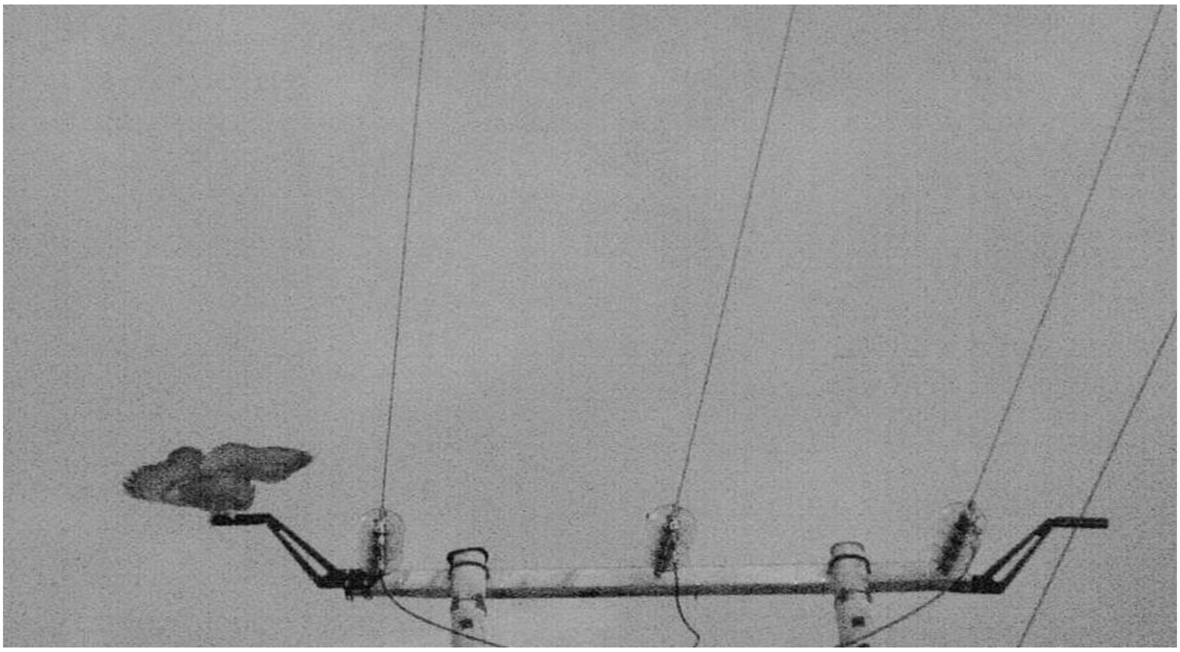


Figure 50. *Eagle owl on elevated perch. Photo: NINA wildlife surveillance camera*.

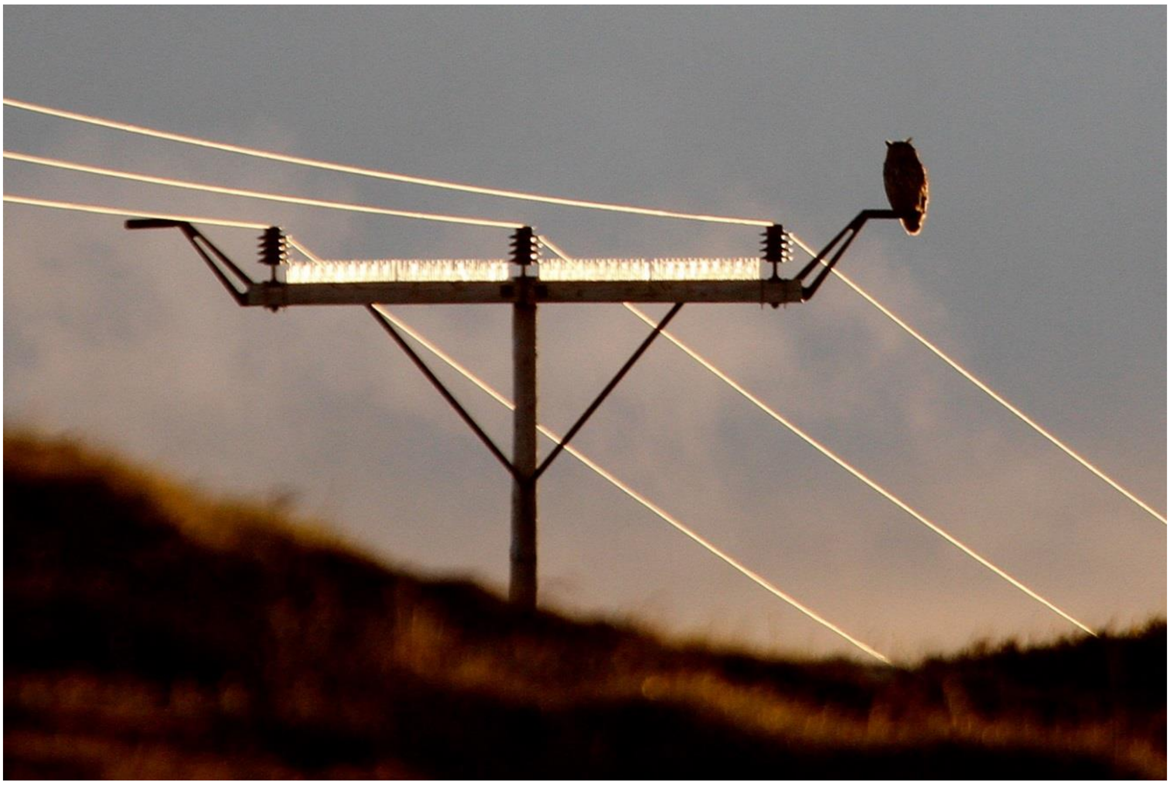


Figure 51. *Eagle owl on elevated perch in June 2012. Photo: Jan Ove Gjershaug*

8 Impact of power-line induced mortality on an eagle owl population

8.1 Background

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 403 and 633 (Heggøy & Øien 2014). 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 eagle owl (Direktoratet for naturforvaltning 2009). The responsibility for the following up of this plan lies at the County Governor in Nordland.

8.2 Study area

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 2009). Solværøyene and Lovund have at most 26 breeding pairs of eagle owls, and the entire Lurøy population could probably consist of 40-50 pairs in good years (Jacobsen et al. 2008). 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 mitigation experiments. The project cooperates with Hedmark

University College, who has provided information about eagle owl breeding success and collected feathers for DNA-analyses. When OPTIPOL was designed, it was decided to take that project on board.

8.3 Methods

8.3.1 GPS satellite telemetry

During 2009-2013, 22 eagle owls were equipped with GPS satellite transmitters; 5 as adults and 17 as nestlings (**Figure 52**). Seven were solar-powered, and 15 battery-driven. The life expectancy of the battery-driven transmitters was approximately one year, while the solar-cell driven ones could in theory give positions for many years. The battery-driven transmitters were programmed to give positions at noon and midnight, while the solar-powered ones were programmed to give a position every hour. The GPS positions are relayed via Argos satellites to base stations, making them available to users after a few hours vi Internet. In cases when GPS positions are not obtained, less accurate positions are provided by the Argos satellites themselves, with an accuracy of down to 150 m, but often more. Argos positions can be used to illustrate large-scale movements. They are classified from 3 (best) to 0, and then from A to B (poorest).

Figure 52. *Two young eagle owls equipped with GPS transmitters in 2012*. Photo: Jan Ove Gjershaug.

8.3.2 DNA analyses

Eagle-owl feathers (plucked and moulted from nestlings and adults) sampled during the project period (2009-2013) have been genotyped using the method described by Kleven et al. (2013).

Briefly, genomic DNA was extracted from the feather calamus using an automated system. A panel of fourteen polymorphic autosomal microsatellite loci and a sex-determination marker were then analyzed to obtain a DNA-profile for each feather. To identify unique DNA-profiles, we used the statistical software package *Allelematch* (Galpern et al. 2012).

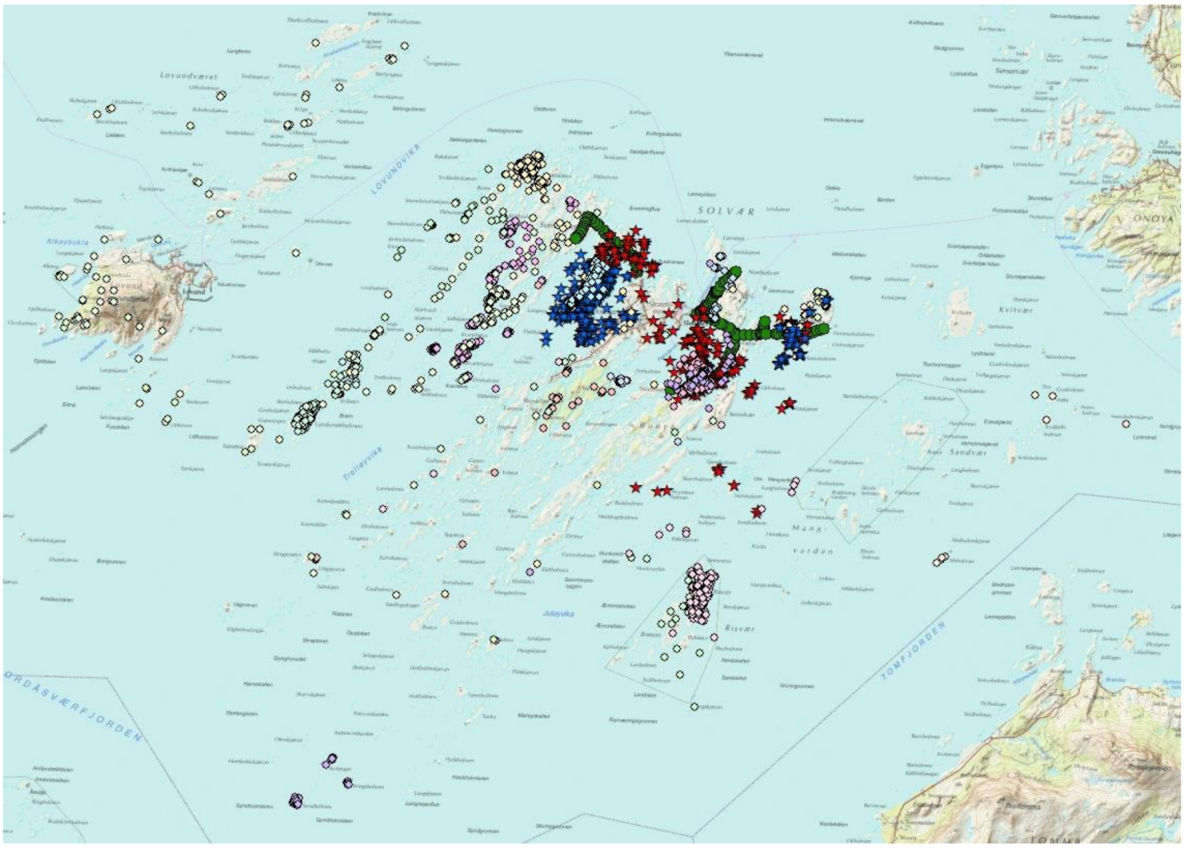
8.3.3 Eagle owl mortality documentation

Searches were carried out beneath all potential dangerous power lines and pylons in the study area to find carcasses of eagle owls and other birds (**Figure 59**).

8.4 Results

8.4.1 GPS satellite telemetry

A total of 4855 GPS positions were obtained; 1440 from adults and 3415 from nestlings. 80 % were from the first calendar year, 19 % from the second calendar year, while only 0.6 % from the third calendar year. In addition, 7053 Argos positions of quality class A or better were received. There was a high juvenile mortality during the first autumn, resulting in a sharp decline in the rate of received positions over time (for all GPS positions from all individuals see **Figure 53)**.



Figur 53. *GPS positions of all eagle owls tagged in Solværøyene. Stars = adults (blue = males, red = females), juveniles = circles, different colors denote different individuals.*

Adults have confined and small territories, and rarely leave more than two km from their nest site. However, females seem to move more than males, especially in the autumn. A female (no. 57268) that we have almost two years of data from, performed excursions out of her territory both 2012 and 2013 in the autumn (**Figure 54**). Males seems to be more confined within their territories (cf. **Figure 55)**.

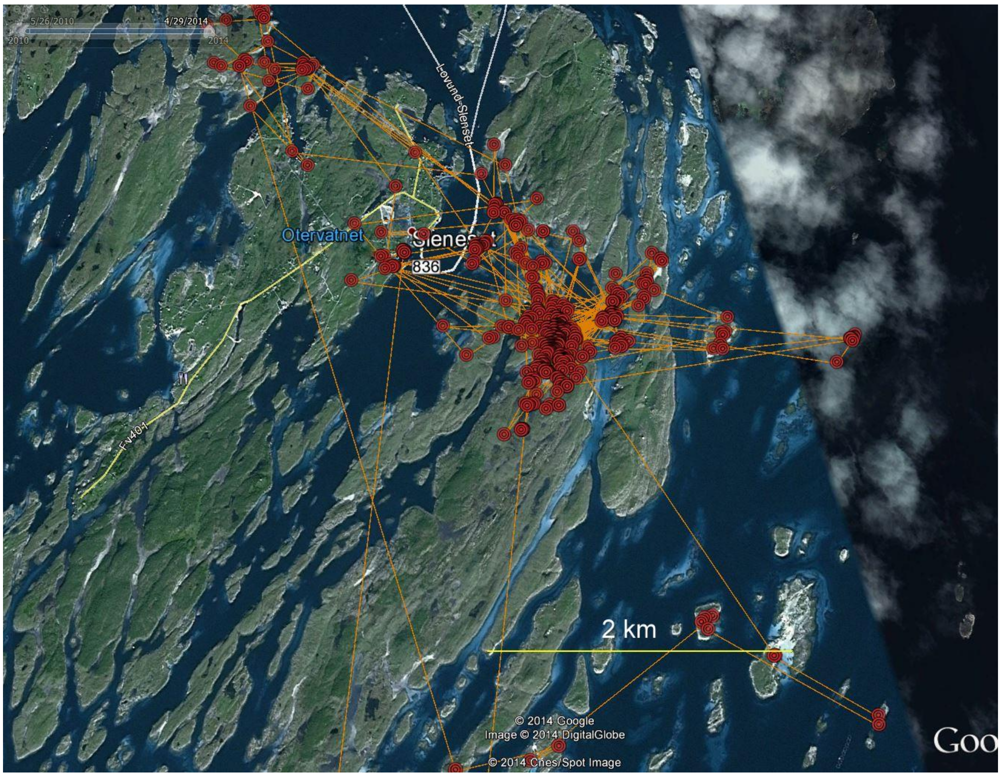


Figure 54. *Movements shown by GPS positions of adult eagle owl female 57268 during 2012-2013. The excursions to the northwest and southeast are performed during the autumns.*

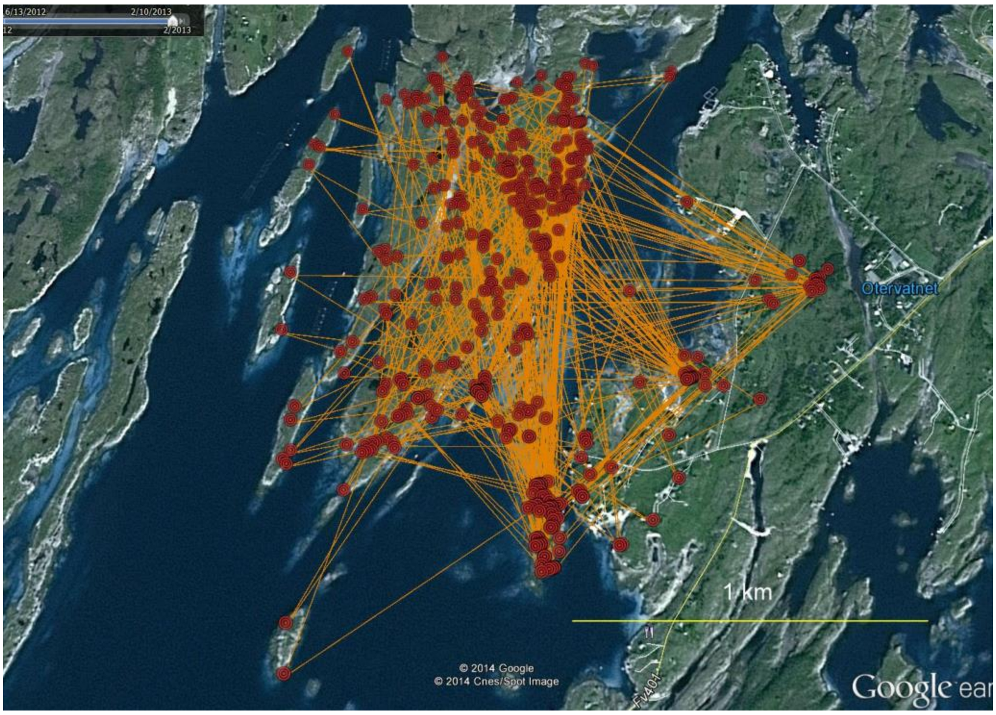


Figure 55. *All positions of adult male 107843, showing a high degree of site fidelity.*

The home ranges are much smaller than recorded for eagle owls at Høg-Jæren/Dalane in Rogaland County (Oddane et al. 2012), and more similar to the situation in some areas in Spain, where Delagado & Penteriani (2007) have used traditional VHF radio telemetry and found mean home range size of 2.7 km² without specifying the estimation method. The home-range of the male in **Figure 55** is approximately 2 km^{2}.. The high eagle owl density at Solværøyan and in some areas in Spain is probably connected to high prey availability.

During autumn, presumably after the adults have quit providing food for the juveniles, they will disperse. Because of the high juvenile mortality during the project period, it is not possible to present a detailed picture of juvenile dispersal. However, many juveniles die within or close to their natal site. Some, however, will set out for excursions within the archipelago (**Figure 56)**. One bird was even believed to have landed on a ship between Solværøyene and Åsvær and was brought west of Røst, judged by its positions, but it was never retrieved.

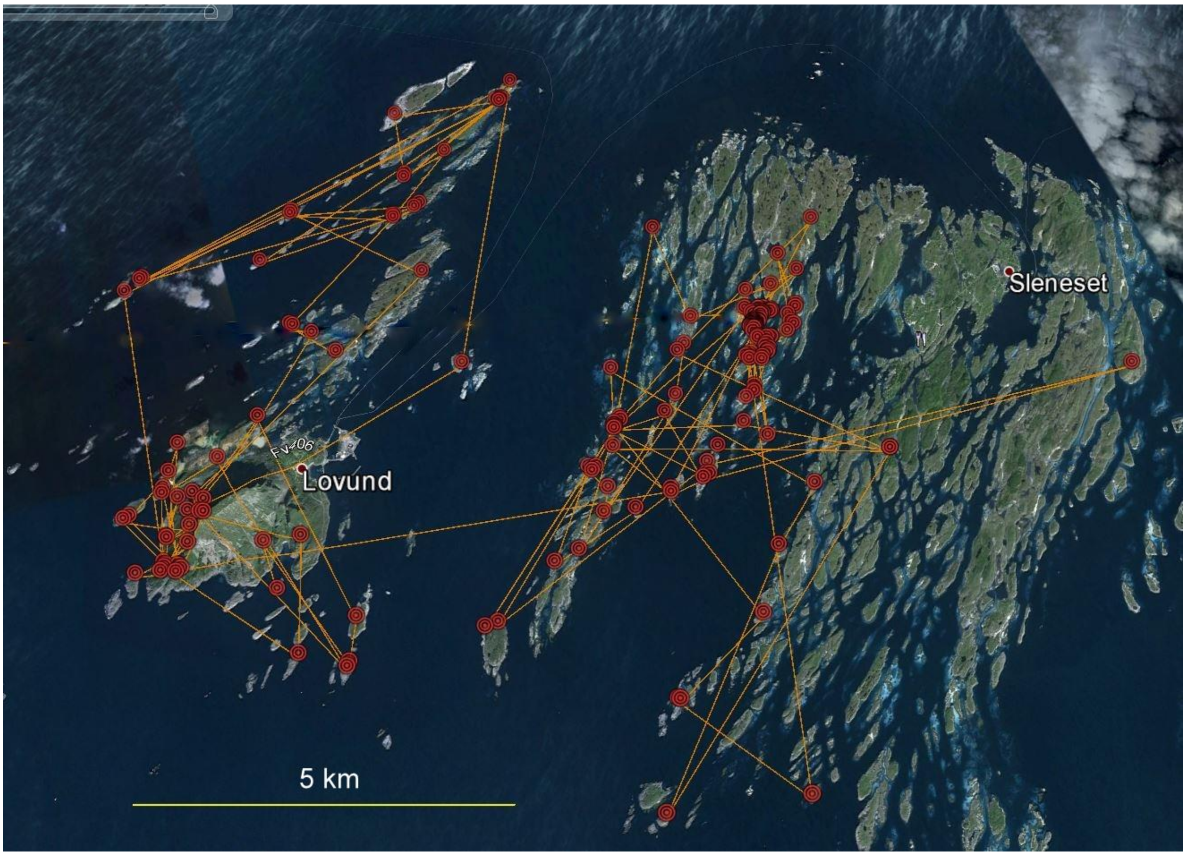


Figure 56. *Juvenile eagle owl no. 115979 tagged in 2012, all positions*.

The dispersal of eagle owl equipped with GPS satellite transmitters in relation to age is shown in **Figure 57**. Adult birds are more inclined to stay in the territory than juveniles, and will therefore show very small dispersal distances. The young birds followed into their second year moved considerably more than the adults.

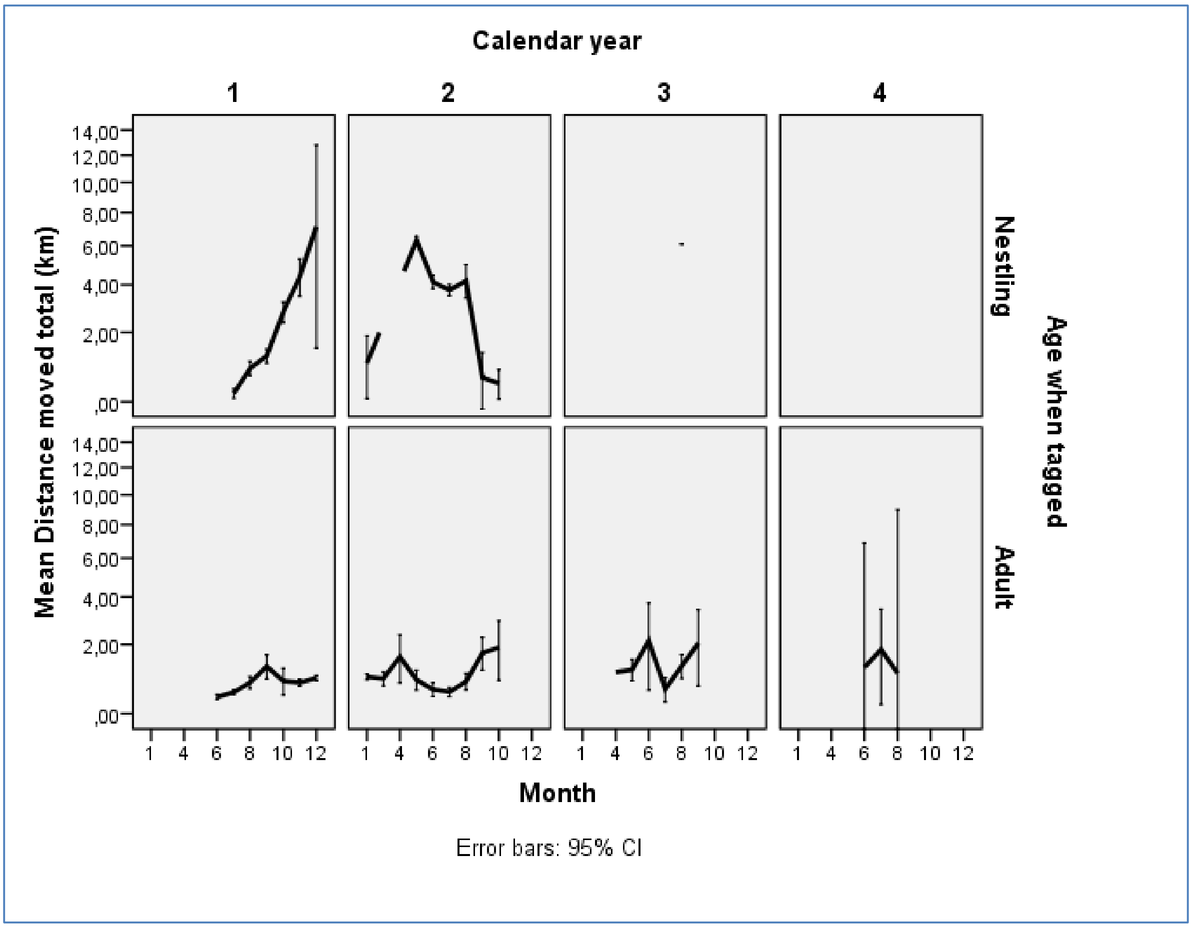


Figure 57. *The mean distance away from nest in relation to age.*

We compared the positions of the tagged birds with the positions of the power-poles. We assumed a GPS accuracy of transmitters to +/- 15 m (the accuracy given by the manufacturer, Microwave Telemetry, Inc., Maryland, USA), and assumed the same accuracy for the position of the poles. We then compared the number of overlapping positions between birds and poles. The most meaningful measure of pole use was believed to be in areas where power-lines crossed an eagle owl territory. A good example was found in the territory of adult female no. 57268 **(Figure 54)**. She gave a total of 647 GPS positions. Of these 144 overlapped with pole positions using the criteria above (22%) (**Figure 58**). Given the uncertainty margins within the method, it does not necessarily mean that all positions indicate a perching bird on a power pole. In some cases the overlap was very small, in other cases there was a very good fit. Also, the bird could be sitting on the ground close to a pole. Therefore, the frequency of overlap should only be regarded as an approximate measure of the frequency of perching on power poles. But, as other parts of this study has shown, the eagle owls at Solværøyane are observed to use the poles frequently, especially at night when they perch during hunting for voles.

Figur 58. *Overlap between power-line poles and GPS-position of a female eagle-owl (GPS-positions small circles, power-line poles large green circles). Overlaps, using circles of 15 m for both types of positions, are shown with brown «crescents».*

8.4.2 DNA analyses

A DNA-profile was successfully obtained from 57% (167/294) of the feathers analyzed. The 167 feathers with a DNA-profile represented 87 unique individuals. Of these 87 unique individuals, 37 were adult individuals and 50 offspring. Among the 37 adult individuals we identified 13 males and 24 females. Based on the DNA-profiles, some of the adults were found to be present in their breeding territory in all five years, while most individuals were observed in fewer years. One of the main ideas with the DNA-profiles was to use them to provide estimates on annual survival of adult breeding eagle owls. However, the current data set is too small to calculating such estimates. Thus, it is not possible to test whether annual survival is related to distance to anthropogenic structures, which may impact eagle owl survival.

8.4.3 Eagle owl mortality documentation

All dead birds recorded beneath power lines/poles during the period 2008-2013 are listed in **Table 3** and **Figure 60.** An overview of all carcasses and remains found beneath power lines/poles in the period 2008-2013 sorted by year and species/group and type of utility structure are listed in **Table 4** and **5**.

No dead eagle owl was found beneath power lines/poles after 2010. One of the five dead eagle owls found in the period 2008-2010 were found in 2008 beneath pole 149 with a pole mounted transformer. Two other dead eagle owls were found beneath the same pole in 2005 (Espen R. Dahl pers. comm.). Another dead eagle owl were found beneath a cable debranching pole (176) in 2008, and one was found beneath pole 177 with double top-insulators in both 2009 and 2010.

After mounting elevated perches and anti-perch devices in October 2011, no dead eagle owls or white-tailed eagles have been recorded in connection to these poles. Only dead crows have been found beneath pole 165 (one in 2012) and pole 175 (two in 2013). It is unclear how these electrocutions have taken place. Crows behave differently from eagle owls and eagles, sometimes appearing in dense flocks and they may perch on different places.

There has been too short time since the elevated perches and anti-perch devices were mounted to evaluate or quantify the bird mortality impact. Some more years with searching are necessary to do that.

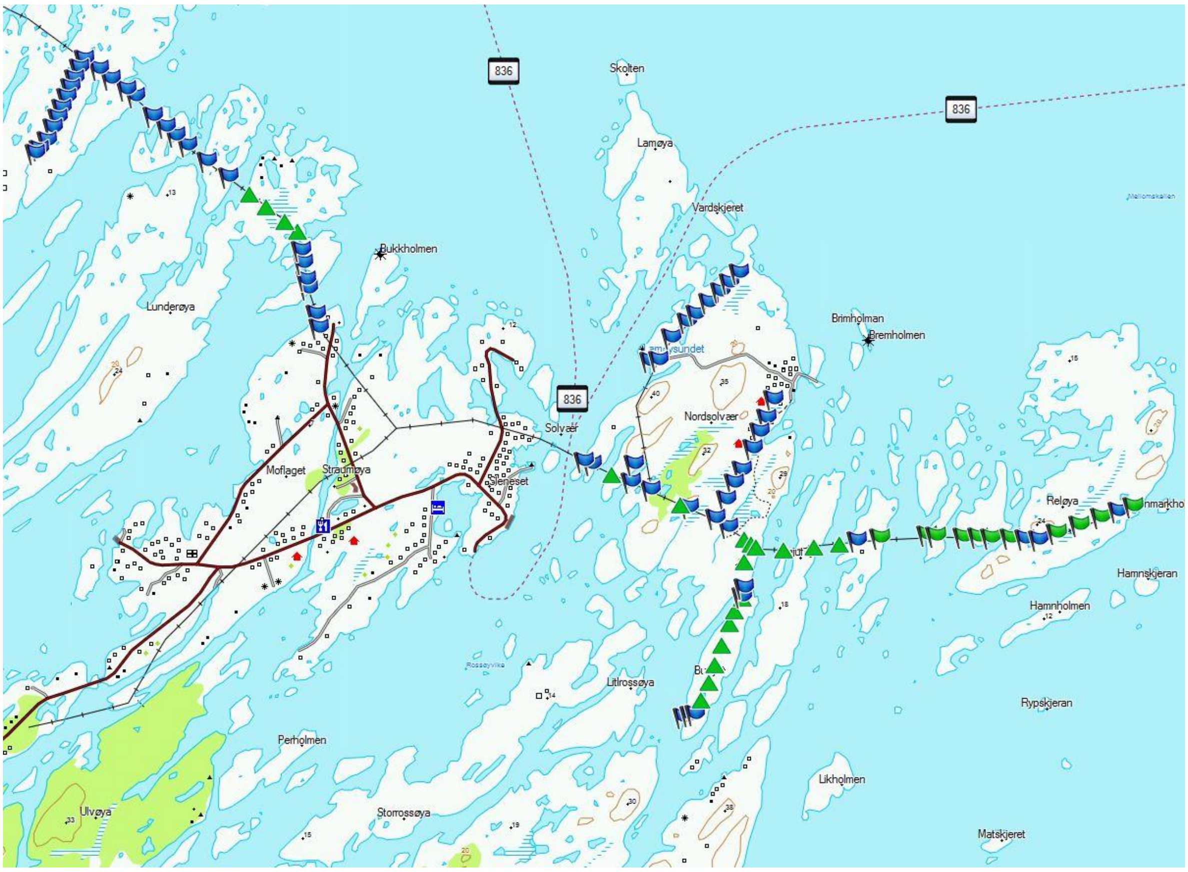


Figure 59. *Poles searched for carcasses with blue flags; removed power line during the study period as green flags, poles with elevated perches and anti-perch devices as green triangles.*

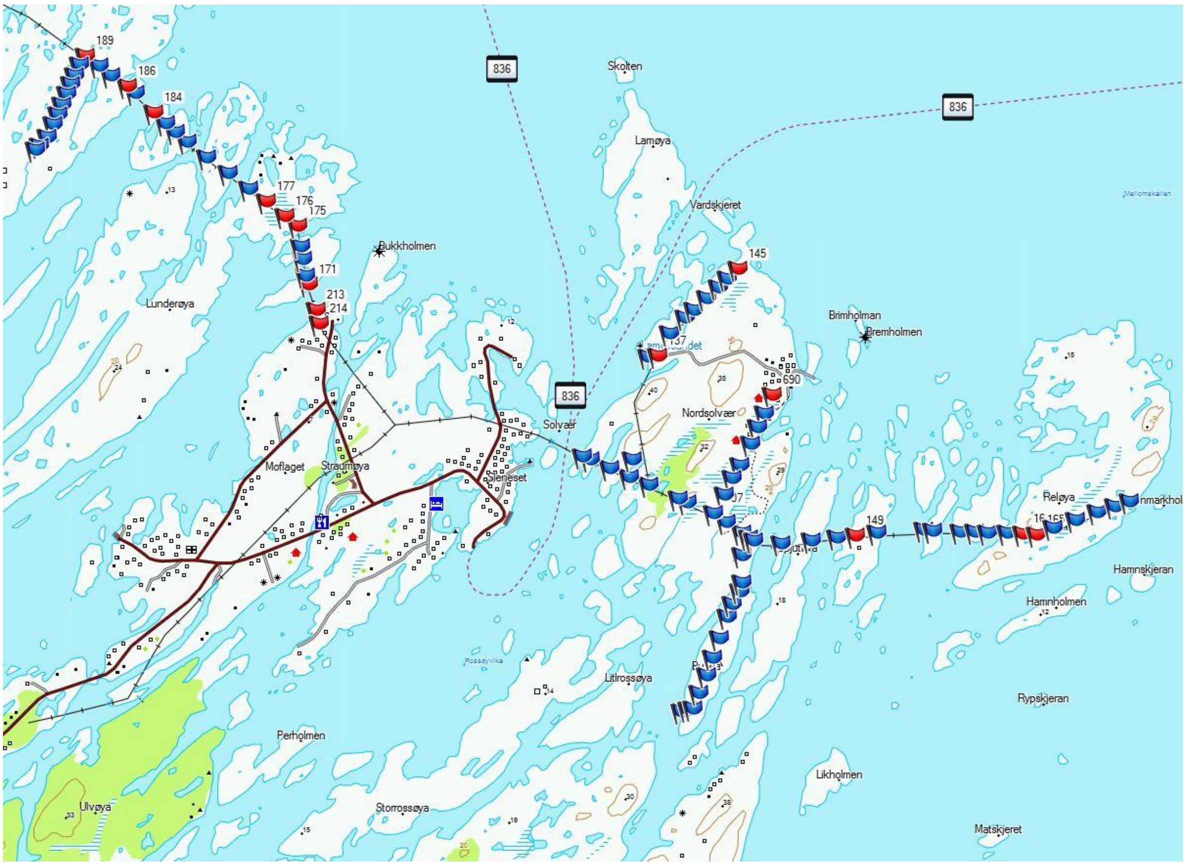


Figure 60. *Poles where electrocuted birds (all species) have been found are marked with red flags. (See also **Table 1**)*

Table 3. *All bird carcasses and remains located beneath power lines/poles in 2008–2013.*

Type of poles	Pylon no.	2008	2009	2010	2011	2012	2013
Power line debranching	107			1 white-tailed eagle (adult)		1 greylag goose (line)	
Cable debranching	137		1 great black-backed gull				
Metal cross-arm	140			1 greylag goose (line)			
Cable debranching	145	1 gull sp.(black-backed/her-ring gull.)	2 hooded crow	1 hooded crow, 1 raven, 1 gull sp.(black-backed/herring gull.)	2 hooded crow	2 hooded crow, 1 grey-lag goose (line)	1 hooded crow
Pole-mounted transformer	149	1 eagle owl (bones)					2 great black-backed gull, 1 hooded crow
Top insulator	164			1 white-tailed eagle (juv.)			
Pole-mounted transformer	165	2 white-tailed eagle	1 white-tailed eagle (re-mains)			1 hooded crow	
Double top insulator	168	1 greylag goose					
Cable debranching	171						1 great black-backed gull
Double top-insulator	175		1 white-tailed eagle (old re-mains)				2 hooded crow
Cable debranching	176	1 eagle owl (from previ-ous winter), 2 hooded crow	1 white-tailed eagle (old re-mains)		3 hooded crow, 1 raven		
Double top-insulator	177	1 white-tailed eagle	1 eagle owl (bones)	1 eagle owl (from previous winter)			
Cable debranching	184	1 eagle owl (bones)			1 oyster-catcher		
Top-insula-tor	186			2 hooded crow	1 hooded crow, 1 raven		
Pole mounted transformer	189			1 hooded crow		1 white-tailed eagle 1 hooded crow	
Cable debranching	213				1 herring gull		
Cable debranching	690					1 great black-backed gull	
Top insulator	694					1 greylag goose (line)	
Top insulator	111					1 white-tailed eagle (line)	
Cable debranching	214					1 herring gull	

Table 4. *All carcasses and remains recorded beneath power lines/poles in the period 2008-2013, sorted by year and species/group.*

Species/ year	2008	2009	2010	2011	2012	2013	Total
	3	1	1				**5**
White-tailed eagle	3	3	2		2		**10**
Crow/raven	2	2	4	8	4	4	**24**
Gulls	1	1	1	1	2	3	**9**
Greylag goose	1		1		3		**5**
Oyster-catcher				1			**1**
Sum per year	**10**	**7**	**9**	**10**	**11**	**7**	**54**

Table 5. *All carcasses and remains found beneath power lines/poles sorted by type of electrical structure. The greylag geese and oystercatcher are probably killed by collision.*

Species/year	Cable debranching	Power line debranching	Metal crossarm	Pole-mounted transformer	Top insulator	Total
Eagle owl	2			1	2	**5**
White-tailed eagle	1	1		4	4	**10**
Crow/raven	9	6		3	6	**24**
Gulls	7			2		**9**
Greylag Goose	1	1	1		2	**5**
Oystercatcher	1					**1**
Sum	**21**	**8**	**1**	**10**	**14**	**54**

Table 6. *« Killer-poles». Poles where dead eagle owls or white-tailed eagles are found are marked with yellow and orange color respectively. Red T marks poles where elevated perches and anti-perch devices were mounted in October 2011.*

2008	2009	2010	2011	2012	2013
#145	#145	#145	#145	#145	#145
#149					#149
#165(2)	#165		T	#165	
#176	#176		#176 T		
#177	#177	#177	T		
#184					
	#137				
	#175		T		#175
		#107			
		#164	T		
		#186	#186		
		#189		#189	
			#213		
				#111	
				#214	
				#690	
					#171

8.4.4 Breeding success

One of our goals was to evaluate how the mortality of adult eagle owls affects the breeding success. The mortality of adult eagle owl in the study area in the period 2008-2013 has however been low (probably because of all mitigation measures before and during the study) making it impossible to address this aspect.

8.5 Conclusions

The GPS satellite telemetry study has given new knowledge on how eagle owl may use the electric pylons during hunting activities. This has also been confirmed by use of wildlife surveillance cameras and direct observations. In an open coastal landscape as Solværøyene, pylons are frequently used by the eagle owl when hunting. The telemetry study has also given new knowledge about home-range size of adult eagle owl and dispersal of juveniles.

Extraction of DNA from feathers collected in eagle owl nests and the following DNA-analyses have been successful. However, there is still too few samples from the same territories across years for proper estimation of adult mortality rates. Hence, there is a need for further sampling of feathers. The DNA analyses will also be a valuable tool for determining to which territory different nests belong. This is important for making an accurate population estimate in Solværøyene which has a very dense eagle owl population.

The search for dead eagle owls and other birds beneath power lines and pylons has given valuable knowledge about high-hazard structures being used when mitigation measures are carried out as a following up of the eagle owl action plan.

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10 Dissemination

10.1 Publications

10.1.1 2009

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.

10.1.2 2010

Bevanger, K., Bartzke, G., Brøseth, H., Dahl, E.L., 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.

10.1.3 2011

Bevanger, K. 2011. Kraftledninger og fugl. Oppsummering av generelle og nettspesifikke problemstillinger. - NINA Rapport 674. 60 s.

Bevanger, K., Bartzke, G., Brøseth, H., Dahl, E.L., Gjershaug, J.O., Hanssen, F., Jacobsen, K.-O., Kvaløy, P., May, R., Meås, R., Nygård, T., Refsnæs, S., Stokke, S. & Thomassen, J. 2011. Optimal design and routing of power lines; ecological, technical and economic perspectives (OPTIPOL). Progress Report 2011. NINA Report 762.

O’Neill, H. 2011. Response of moose *(Alces alces)* to power-line rights-of-way/forest edges in Norway. University of Leeds, Leeds, UK (passed with distinction)

Rochelle, S. 2011. Effects of power lines and their possible effects on the browsing behaviour of Moose *(Alces alces)* in Norway and how this relates to the browsing material available across Norway. University of Leeds, Leeds, UK.

10.1.4 2012

Benjaminsen, J.T. & Refsnæs, S. 2012. Kabel eller Luftledning. AN12.12.01. SINTEF Energi AS, Trondheim.

Brøseth, H., Nilsen, E.B. & Pedersen, H.C. 2012. Temporal quota corrections based on timing of harvest in a small game species. European Journal of Wildlife Research. 1612-1642 DOI 10.1007/s10344-012-0625-3.

Magnusson, N. 2012, Bird electrocution prevention insulation systems for 12-24 kV pin insulated overhead lines. AN 10.12.38. SINTEF Energi AS, Trondheim.

Refsnæs, S. 2012. Fargede liner - muligheter og begrensninger ved bruk av kamuflasjeliner. AN 10.12.106. SINTEF Energi AS, Trondheim.

Refsnæs, S. 2012. Aldring av liner under fuglebeskyttelse i mastetopp. AN 10.12.30. SINTEF Energi AS, Trondheim.

Refsnæs, S., Kvien, O & Brede, A.P. 2012. Sittepinne og plastpiggmatte i mastetopper. AN 12.12.27.

Refsnæs, S., Magnusson, N. & Ulleberg, T. 2012. Laboratory Corrosion Tests on Overhead Line Conductors with Bird Protection Systems. European Transactions on Electrical Power.

Stenshornet, K., Refsnæs, S. & Heggset, J. 2012. Feilfrekvens ved driftsforstyrrelser for kraftledning og kabel. AN 10.12.83. SINTEF Energi AS, Trondheim.

Thomassen, J., Hanssen, F., May, R. & Bevanger, K. 2012. Optipol Least Cost Path dialog - Rapport fra dialogseminar om tema, deltema og kriterier i Optipol-LCP versjon 1.0. NINA Report 856.

10.1.5 2013-2014

Bartzke, G. 2014. Effects of power lines on moose (*Alces alces*) habitat selection, movements and feeding activity. – PhD Thesis, NTNU, Trondheim, Norway.

Bartzke, G., May, R., Stokke, S., Røskaft, E. & Engen, S. (in print). Comparative effects of power lines and roads on moose (*Alces alces*) habitat selection. Environmental Concerns in Rights-Of-Way Management. Proceedings from the Tenth Symposium. Phoenix, AZ, USA, September 30-October 3, 2012.

Bartzke, G.S., May & R., Røskaft, E. (manuscript). Differential barrier and corridor effects of power lines, roads and rivers on moose (*Alces alces*) movements.

Bartzke, G.S., May, R., O'Neill, H., Rochelle, S. & Stokke, S. (manuscript). Edge effects at a high-voltage power line on moose (*Alces alces*) browsing and habitat use.

Bartzke, G.S., May, R., Bevanger K., Stokke S. & Røskaft, E. (in print) A review on the effects of power lines on ungulates and its implications for power line routing and rights-of-way management. - International Journal of Biodiversity and Conservation.

Bevanger, K., Dahl, E.L., Gjershaug, J.O., Magnusson, N. & Refsnæs, S. 2014. Challenges and opportunities in preventing bird electrocution in Coastal Norway. – Proceedings International Conference on Overhead Lines. Design, Construction, Inspection & Maintenance. EDM, March 31-April 3, 2014. Fort Collins, Colorado USA. 14 pp.

Bevanger, K. & Refsnæs, S. 2013. Possibilities and constraints in reducing bird collision and electrocution in the existing power-line grid in Norway. - NINA Report 763. 62 pp.

Bevanger, K. & Refsnæs, S. 2013. Power line camouflaging. Assessments of ecological and technical implications - NINA Report 878. 46 pp.

Brøseth, H. & Bevanger, K. (in print). Black grouse and capercaillie mortality and population estimates by DNA identification in relation to powerline ROW. - Environmental Concerns in Rights-Of-Way Management. Proceedings from the Tenth Symposium. Phoenix, AZ, USA, September 30-October 3, 2012.

Gjershaug, J.O., Refsnæs, S. & Bevanger, K. (in print). Mitigation of eagle owl electrocution in Norway. Environmental Concerns in Rights-Of-Way Management. - Proceedings from the Tenth Symposium. Phoenix, AZ, USA, September 30-October 3, 2012.

Hanssen, F., Thomassen, J., May R. & Bevanger, K. (in print). A Least-Cost-Path (LCP) toolbox for optimal routing of power lines. Environmental Concerns in Rights-Of-Way Management.

Proceedings from the Tenth Symposium. Phoenix, AZ, USA, September 30-October 3, 2012.
Refsnæs, S, Magnusson, N. & Ulleberg, T. 2013. Laboratory corrosion tests on overhead line conductors with bird protection systems. - International Transactions on Electrical Energy Systems. DOI: 10.1002/etep.1770.

10.2 Lectures and conference participation

10.2.1 2010

Bartzke, G. 2010. Effects of power-line rights-of-way (ROW) vegetation management on habitat use, movement and behaviour of wildlife. Lunchseminar at NINA. Trondheim 08.04.

Bartzke, G. 2010. Effects of power line rights-of-way (ROW) vegetation management on habitat use, movement and behaviour of wildlife. CEDREN PhD meeting. Trondheim 14.04.

Bartzke, G. 2010. 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.

Bartzke, G. 2010. Potential of power-line rights-of-way as habitat resources for moose *(Alces alces)* and other wildlife. CEDREN Scientific Committee. Trondheim 27.10.

Bartzke. G. 2010. Power lines as wildlife biotopes. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Bevanger, K. 2010. NINA, BirdWind og OPTIPOL. Møte med OED. Trondheim 16.11.

Bevanger, K. 2010. BirdWind & OPTIPOL. CEDREN Scientific Committee. Trondheim 26.10.

Bevanger, K. 2010. OPTIPOL. Seminar om FoU på bærekraftig energiproduksjon, CEDREN og DNs Energiteam. Trondheim 08.01.

Bevanger, K. 2010. Project status, new applications etc. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Bevanger, K. 2010. Immediate actions to reduce mortality among birds due to power lines. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Brøseth, H.2010. Power lines as a mortality factor for tetraonids. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Dahl, E.L. 2010. Bird electrocution recordings along the Smøla grid. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Hanssen, F.A. 2010. A ”least-cost path” GIS-based application for optimal routing of power lines. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Husdal, M.M. 2010. Status on the National Action Plan for the eagle owl. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Gjershaug, J.O. 2010. Status on the eagle owl project at Sleneset. OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 22.

Kvaløy, P. 2010. 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. 2010. Optimal design and routing of power lines; ecological, technical and economic perspectives (OPTIPOL). CEDREN generalforsamling, Trondheim 06.05.

Meås, R. 2010. 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. 2010. 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. 2010. NINA, OPTIPOL. Presentasjon for CEDREN Reference Group - BirdWind og OPTIPOL. Trondheim 19.10.

10.2.2 2011

Bartzke, G. 2011. Potential of power-line rights-of-way as habitat resources for moose (*Alces alces*) and other wildlife. – OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 17.
Bartzke, G., May R., Hedger R., Rolandsen C., Solberg E., Stokke S., Røskaft E. 2011. Effects of power lines on moose *(Alces alces)* movement and habitat selection. IRSAE conference. Evenstad 09.08. - won price for best presentation
Bevanger, K. 2011. Research activities on birds and power lines at CEDREN (Centre for Environmental Design of Renewable Energy). – Side-event at COP10/UNEP/CMS Bergen 20.-25. November.
Bevanger, K. 2011. Power lines - environmental impacts. - Lecture at NTNU/ESIA 08.11.
Bevanger, K. 2011. Prosjektstatus. – OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 17.
Brøseth, H.2011. Kraftledninger og dødelighet hos skogsfugl. - OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 17.
Dahl, E.L. 2011. Kartlegging av elektrokusjonsfare på Smøla. - OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 17.
Hanssen, F., May, R. & Thomassen, J. 2011. Least Cost Path (LCP) modell for optimalt trasevalg av kraftledninger. Status november 2011. - OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 17.
Gjershaug, J.O. 2011. Hubro i Lurøy. - OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 17.
Jacobsen, K.-O. 2011. Eagle Owl study in Lurøy (OPTIPOL). Eagle Owl seminar. Rica Hell Hotel Stjørdal, Desember 1-2.
Kvaløy, P. 2011. Nasjonal database for registrering av fugl drept pga. kollisjon/elektrokusjon. - OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 17.
Refsnæs, S. 2011. Tekniske muligheter og begrensninger av tiltak, som kan redusere faren for fuglekollisjoner eller elektrokusjon. - OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 17.
Refsnæs, S. 2011. Technical possibilities and constraints to reduce the bird mortality in connection to power lines. Eagle Owl seminar. Rica Hell Hotel Stjørdal, Desember 1-2.
Stokke, S. 2011. Forsøk med rydding etter alternative kriterier langs kraftlinjer. - OPTOPOL Annual Meeting, Rica Hell Hotel Stjørdal, November 17.

10.2.3 2012

Bartzke, G., May, R. Rolandsen, C., Solberg & Engen, S. 2012. Everything is relative - or what? How to calculate total step selection probabilities. IRSAE Summer school; Evenstad; 13-17 August.
Bartzke, G., May, R. Rolandsen, C., Solberg, E., Stokke, S., Røskaft, E., Hedger, R. & Engen, S. 2012. Comparative effects of power lines and roads on moose (*Alces alces*) habitat selection. Environmental Concerns In Rights-Of-Way Management. The Tenth Symposium. Phoenix, AZ, USA, September 30-October 3.
Brøseth, H. & Bevanger, K. 2012. Black grouse and capercaillie population estimates by DNA identification. Environmental Concerns In Rights-Of-Way Management. The Tenth Symposium. Phoenix, AZ, USA, September 30-October 3.
Gjershaug, J.O., Refsnæs, S. & Bevanger, K. 2012. Mitigation of eagle owl electrocution in Norway. Environmental Concerns In Rights-Of-Way Management. The Tenth Symposium. Phoenix, AZ, USA, September 30-October 3.
Hanssen, F., Thomassen, J., May R. & Bevanger, K. 2012. Optimalt trasevalg for kraftledninger. NINA-styremøte, Trondheim.
Hanssen, F., Thomassen, J., May R. & Bevanger, K. 2012. Optimalt trasevalg for kraftledninger. OPTIPOL Least Cost Path (LCP). OPTIPOL brukermøte, Trondheim.
Hanssen, F., Thomassen, J., May R. & Bevanger, K. 2012. A Least Cost Path toolbox for optimal routing of high voltage power lines. 32nd Annual Conference of the International Association

for impact assessment. Energy Future. The Role of Impact Assessment; Porto, Portugal; 27 May – 1 June.
Hanssen, F., Thomassen, J., May R. & Bevanger, K. 2012. Toolbox for optimal routing of high voltage power lines. ESRI European GIS User Conference. Oslo, Norway 18-20. October
Hanssen, F., Thomassen, J., May R. & Bevanger, K. 2012. A Least-Cost-Path (LCP) toolbox for optimal routing of power lines. Environmental Concerns In Rights-Of-Way Management. The Tenth Symposium. Phoenix, AZ, USA, September 30-October 3.

10.2.4 2013-2014

Bevanger, K. 2013. Wind energy generation and power transmission – environmental impacts. - Indo-Norwegian seminar, Mumbai, India 7-8 May 2013.
Bevanger, K. 2014. Challenges and opportunities in preventing bird electrocution in Coastal Norway. International Conference on Overhead Lines, March 31-April 3, 2014, Fort Collins, Colorado U.S.A.
Hanssen, F. 2013. Spatial Multi Criteria Analysis for conflict mapping and optimal siting or routing of technical installations. Meeting at The European Incoherent Scatter Scientific Association (EISCAT), Kiruna.
Hanssen, F. 2013. Spatial Multi Criteria Analysis for conflict mapping and optimal siting or routing of technical installations. Møte på STATOIL, Oslo.
Hanssen, F., Thomassen, J., May R. & Bevanger, K. 2013. Optimal rute for ledningstraseèr. Vi kan finne den. CEDREN Generalforsamling, Trondheim.
Hanssen, F. 2013. Optimal planlegging - fra konflikt til mulighet. CEDREN Seminar, Trondheim
Hanssen, F., Thomassen, J., May R. & Bevanger, K. 2013. Least-cost path (LCP) analysis for optimal routing of high-voltage power lines: A spatially explicit MCA. CEDREN MCA Seminar, Trondheim.
Hanssen, F. 2013. Med dialog og GIS som verktøy i arealkonflikter. - NINA`s miljødag.
May, R., Bevanger, K., van Didjk, J., Petrin, S. & Brende H. Renewable energy: consequences for biodiversity and ecosystem services. NØF conference, Trondheim.
Hanssen, F. May, R. & Thomassen, J. 2014. Dialog og konfliktreduksjon. Planverktøy for optimal lokalisering av infrastruktur. NINA Lunch seminar, Trondheim.
Hanssen, F., Thomassen, J., May R. & Bevanger, K. 2014. OPTIPOL LCP 2.0. Et verktøy for fremtidens kraftledningsbyggere? Avsluttende brukermøte i OPTIPOL, Trondheim.
Hanssen, F 2014. Conflict resolution. Norwegian activities and experiences. Meeting at Laboratory of Avian Ecology, Nature Research Centre, Vilnius.
Hanssen, F. & May, R. 2014. Verktøy for bedre lokalitetsvalg? Vindkraft og sentralnett. SRN Vindkraftkonferanse, Oslo.
Jacobsen, K.-O. 2013. Hubro. Status og bestandsforhold. Forskning på Helgelandskysten. Foredrag 9.4.2013 på medlemsmøte for NOF, Tromsø lokallag. 54 tilhørere.
Jacobsen, K.-O. 2013. Hubro. Status og bestandsforhold. Forskning på Helgelandskysten. Foredrag 9.4.2013 på medlemsmøte for NOF, Lyngen og omegn lokallag. 15 tilhørere.
Jacobsen, K.-O. 2013. Kartlegging av farlige stolpekonstruksjoner i Lurøy. Møte i nasjonal referansegruppe for hubro. Sleneset, Lurøy 27.08.2013.

10.3 Coverage in public media

10.3.1 2009

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

10.3.2 2011

NRK Trøndelag Radio – 18.03.2011. Skogsfugltelling i Ogndalen (H. Brøseth).

Helgelands Blad – 22.07.2011. Satellittmerker hubro på Solværøyene (Lie-Dahl).
Helgelands Blad – 26.09.2011. Nordland parkert i Norges satsing på fornybar energi (J.O. Gjershaug).
UNEP.org. 24.11.2011. - UN Wildlife Meeting Pushes to Make Power Lines Safer for Birds (K. Bevanger).
PressReleasePoint 25.11.2011. UN Wildlife Meeting Pushes to Make Power Lines Safer for Birds (K. Bevanger).
Norsk institutt for naturforskning – 25.11.2011. Redder hubro fra grilling (K. Bevanger, S. Refsnæs).
IEWY News – 28.11.2011. UN Wildlife Meeting Pushes to Make Power Lines Safer for Birds (K. Bevanger).
NRK Nettavis – 29.11.2011. Denne pinnen skal hindre hubrogrilling (K. Bevanger, S. Refsnæs).
Avisa Nordland - 29.11.2011. Sittepinner skal redde hubro (K. Bevanger, S. Refsnæs).
Miljøverndepartementet - 30.11.2011. Redder hubro fra grilling (K. Bevanger, S. Refsnæs)
Adresseavisen – 30.11.2011. Slutt på hubro-grilling (K. Bevanger, S. Refsnæs).
Trønder-Avisa – 30.11.2011. Slutt på hubro-grilling (K. Bevanger, S. Refsnæs).
MyNewsdesk Norge – 01.12.2011. Redder hubro fra grilling (K. Bevanger, S. Refsnæs).
Romerikes Blad 01.12.2011. Slutt på hubro-grilling (K. Bevanger, S. Refsnæs)
Nordlys 01.12.2011. Slutt på hubro-grilling (K. Bevanger, S. Refsnæs).
Adresseavisen 01.12.2011. Slutt på hubro-grilling (K. Bevanger, S. Refsnæs).
Finnmark Dagblad 02.12.2011. Slutt på hubrogrilling (K. Bevanger, S. Refsnæs).
Fremover 02.12.2011. Hubro får egen sitteplass på strømstolper (K. Bevanger, S. Refsnæs).
Demokraten 02.12.2011. Slutt på hubrogrilling (K. Bevanger, S. Refsnæs).
NRK Nordland 29.11.2011. Denne sittepinnen skal hindre hubrogrilling (Gjershaug, Refsnæs). http://nrk.no/nyheter/distrikt/nordland/1.7893792
Forskning.no. 1.12.2011. Slutt på hubrogrilling. http://www.forskning.no/kortnytt/305997.
P4 30.11.2011. Ikke mer hubro-grilling. http://www.p4.no/story.aspx?id=440954
Regjeringen.no. 30.11.2011. Redder hubro fra grilling.http://www.regjeringen.no/nb/dokumentarkiv/stoltenberg-ii/md/Nyheter-og-pressemeldinger/nyheter/2011/redder-hubro-fra-grilling.html?id=664927
Vil verne trekkfugler mot kraftlinje-død. 24.11.2011. http://www.tu.no/kraft/2011/11/24/vil-verne-trekkfugler-mot-kraftlinje-dod
Tiltak for berging av hubro. 30.11.2011. http://spekkhogger.no/?p=870
Rana Blad 5.1.2012 http://www.ranablad.no/nyheter/article5868708.ece

10.3.3 2012

Nytt fra CEDREN nr. 3 – 2012. Finner optimal rute.
Nytt fra CEDREN nr. 2 – 2012. Optimal trasévalg for kraftledninger.
Bergens Tidende 17.10.2012. Denne sittepinnen reddar hubroliv. http://www.bt.no/nyheter/lokalt/Denne-sittepinnen-reddar-hubroliv-2781999.html
Energibransjen.no. 18.10.2012. Sittepinne kan redde hubroen. http://www.elektronett.no/default.asp?menu=2&id=2800
Rana Blad. 5.1.2012. Sittepinner redder hubro. http://www.ranablad.no/nyheter/article5868708.ece
FM i Nordland. 3.1.2012. http://www2.fylkesmannen.no/hoved.aspx?m=58293&amid=3555291
http://www.regjeringen.no/nb/dep/md/aktuelt/nyheter/2011/redder-hubro-fra-grilling.html?id=664927
Bygg.no. 2012. http://www.bygg.no/2011/11/slutt-paa-hubro-grilling.
An.no. 6.1.2012. Vil redde hubroer fra grilling. http://mobil.an.no/nyheter/article5871208.ece.
Vol.no. Hjelp til hubro. http://www.vol.no/nyheter/article550939.ece
Webavisen. Hubro. http://www.webavisen.no/siste-nytt-om/hubro.htm
Gemini. Sittepinner skal redde hubro. http://www.ntnu.no/gemini/2012-01/42-43.htm
BKK.no. 16.10.2012. Sittepinne kan redde hubroen. http://www.bkk.no/om_oss/media/Nyheter_og_pressemeldinger/article36424.ece

Blar opp 4,5 millioner for å redde hubroen. 22.5.2012. http://www.nrk.no/nordland/vil-berge-ut-ryddningstruet-ugle-1.8148485

10.3.4 2013-2014

Designer-kraftledninger reduserer fugledød 10.2.2014 (Bevanger) http://jaktogfiskeavisa.no/index.php/naturfoto2/item/446-designer-kraftledninger-reduserer-fugledod
Designer-kraftledninger reduserer fugledød. 10.2.2014 http://www.forskning.no/artikler/2014/februar/380516
Tester design-kraftledninger mot fugledød. 13.3.2014. (Bevanger) http://www.njff.no/portal/page/portal/njff/nyhet?element_id=248100113&displaypage=TRUE

11 Appendix

Program utsendt til brukermøtet i OPTIPOL 2014 – 4. februar kl. 1000-1500, NINA-huset, Trondheim

De fleste aktiviteter i CEDREN-prosjektet OPTIPOL ble formelt avsluttet ved utgangen av 2013 og det arrangeres i den anledning avsluttende brukermøte på NINA-huset tirsdag 4. februar. Møtet blir todelt; sesjonen før lunsj oppsummerer noen av prosjektets aktiviteter. Tiden etter lunsj ønsker vi å benytte til å diskutere hva som er viktige kunnskapsbehov videre i forhold til nett – både fra forvaltningen og netteiers side. Vi tar sikte på å avslutte møtet omkring kl. 1500. Velkommen!

Program:

1000-1020	Velkommen; kort oppsummering av OPTIPOL (Kjetil Bevanger)
1020-1050	LCP. Et verktøy for fremtidens kraftledningsbyggere? (Frank Hanssen)
1050-1120	Kraftledningsgater – til nytte eller besvær? (Sigbjørn Stokke)
1120-1150	Bestandsestimering og kollisjonsdødelighet hos storfugl og orrfugl i Ogndalen (Henrik Brøseth)
1200-1245	Lunsj
1245-1500	Kraftledninger og miljø. Fremtidige kunnskapsbehov?

Ca. 5 min innledning fra
Svein Grotli Skogen – kunnskapsbehov fra et miljøforvaltningsperspektiv (Miljødirektoratet)
Håvar Røstad- fra et energiforvaltningsperspektiv (NVE)
Asgeir Vagnildhaug – fra et utbyggerperspektiv (Statnett)
Audun Ruud fra SINTEF gir en kort innledning omkring hvilke samfunnsmessige utfordringer som er identifisert gjennom bl.a. **Susgrid-prosjektet**.

Aktuelle tema for videre diskusjon:

Fra Statnetts side ble det under siste brukermøte i OPTIPOL (19. november 2012) påpekt at forholdene nå ligger til rette for undersøkelser før utbygging samt langsiktig oppfølging etter utbygging for å få ***gode effektstudier*** i forhold til ulike miljøpåvirkninger. På samme måte som i tilknytning til vindkraftutbygging vil «samlet belastning» også være et viktig tema når det gjelder nett. Er det for eksempel aktuelt med et langsiktig miljøovervåkingsprogram?

Testing og videreutvikling av ***Least-Cost-Path/Least-Cost-Siting metodikken***. Metodikken og verktøyet har vakt betydelig interesse innen flere fagområder både nasjonalt og internasjonalt (i forhold til bl.a. «samlet belastning», arealplanlegging, ressursforvaltning, pumpekraft, nettplanlegging, offshore rørinstallasjoner, radarinfrastruktur og fiskeoppdrett). OPTIPOL LCP 2.0 ferdigstilles i disse dager og det er viktig å få estimert verktøyets effektiviseringspotensial i forhold til medgått tid og kostnader knyttet til tradisjonelt utredningsarbeid.

Kraftledninger/kraftledningsgater – utfordringer i forhold til landskapsdesign; viltbiotop og spredningskorridor; kanteffekter og biologisk mangfold; barriere-/semibarriere-problematikk; fragmenteringsproblematikk, fuglekollisjoner/bestandseffekter, stedsspesifikke karakteristika ved kollisjonspunkter m.m.

Kartlegging av fugletrekk er et lite vektlagt tema i Norge i tilknytning til forundersøkelser og konsekvensutredninger til tross for at NVE i flere konsesjonsbetingelser spesifiserer krav til fugletrekk-kartlegging. Utbygger definerer pålegget dit hen at undersøkelsen skal skje «på bakgrunn av eksisterende kunnskap» da det tidligere ikke har vært praktisk gjennomførbart å foreta gode kvalitative og kvantitative fugletrekkundersøkelser. Gjennom fugleradarer er metoden og verktøyet nå på plass. Er det behov for klarere retningslinjer/forskrifter fra energi- og miljøforvaltningen som utdyper/spesifiserer hva som ligger i konsesjonskrav om fugletrekkundersøkelser?

Samfunnsmessige utfordringer. Konfliktene knyttet til Sima-Samnanger prosjektet sommeren 2010 – den såkalte «monstermastdebatten», viste i klartekst sprengkraften i samfunnsengasjementet og det skapte da også endringer i nettpolitisk praksis. Med ny Nettmelding som Stortinget vedtok enstemmig i mai 2012 er planprosesser endret, og for nye prosjekt i sentralnettet skal det nå gjennomføres ekstern kvalitetssikring av såkalte konseptvalgutredninger (KVU) som så skal klareres politisk i OED før tiltakshaver melder konkrete nettutviklingsprosjekt. Med «monstermastdebatten» friskt i minne er håpet at man skaper større forståelse for rådende behov, og hvorfor eventuelt det meldte nettprosjekt bør bygges. De nye nettpolitiske prosedyrer er dog kun begrenset til nytt sentralnett og lite er forandret hva gjelder regionalnettet eller oppgradering av eksisterende sentralnett. Fortsatt er det derfor store samfunnsmessige utfordringer knyttet til konkret lokalisering, finansiering og den miljø- og samfunnsmessige nytte som prosjektet kan skape.

Områdekonsesjon. Tapsprosesser vis a vis biologisk mangfold er ofte «resultanten» av kumulative miljøpåvirkninger og isolerte beslutninger innen forvaltning og politiske fora. Det gjelder også utbygging av kraftledningsnettet der områdekonsesjonssystemet kan føre til en lite helhetlig vurdering. Fragmentering og omdanning av habitater, påvirker de dynamiske prosesser et økosystem er avhengig av for at det biologiske mangfoldet skal kunne opprettholdes. Kraftledningsetablering uten konsekvensvurderinger er del av en kontinuerlig prosess der tallrike enkeltinngrep gjennomføres uten at det er mulig å koordinere eller overskue konsekvensene i et større tids- og romperspektiv. Dette er forhold som så langt er lite fokusert i Norge, det være seg i forhold til kraftledninger, gjerder, veier, jernbane eller annen infrastruktur. Ved siden av å fremstå som barrierer i klassisk forstand, vil det økologiske influensområde i tilknytning til denne type lineære strukturer kunne være meget bredt.

Distribusjonsnettene utgjør den klart største delen av det norske kraftledningsnettet, og i tilknytning til dette er elektrokusjonsproblematikken i flere sammenhenger blitt påpekt. **Forebyggende tiltak mot elektrokusjon** av hubro ble av forrige regjering utpekt som et satsingsområde og det ble bevilget 30 millioner til formålet. Det er satt i gang tiltak en rekke steder i landet med bl.a. OPTIPOL-sittepinnen, fugleavvisere, Uven-huven o.l. Fra CEDREN er det ved flere anledninger påpekt at det ville vært naturlig med en overordnet strategi der elektrokusjonsproblematikken ble sett i et større og mer helhetlig perspektiv – bl.a. hvilke tiltak som bør prioriteres i ulike landsdeler i forhold til kartlagte risikostrukturer. Det er også sendt to søknader til NFR om finansiering til et slikt prosjekt uten at dette så langt er gitt positive resultater. En evaluering/etterundersøkelser i forhold til de tiltak som allerede er implementert på bakgrunn av de 30 millionene som nå brukes er også et aktuelt tema.

CEDREN har nylig utgitt «*Håndbok for miljødesign i regulerte laksevassdrag*» - et produkt basert på ENVIDORR. Er det av interesse å få å utarbeidet en håndbok designet for brukersiden når det gjelder nett?

Korte innlegg fra brukersiden om fremtidige kunnskapsbehov

Miljødirektoratet -Svein Grotli Skogen

Ønsker kunnskap om **generelle sammenhenger** – typetall, hovedsammenhenger (også like interessant hva slags sammenhenger man ikke finner). Viktig med **god kvalitet på studiene** – må bruke nok tid og god design. **Tverrfaglige problemstillinger** – LCP er et støttesystem på generiske tema, men kan appliseres på kraftlinjer, og kan også brukes på vegnett – åpent for bred applisering – viktig å koble det til de mulige anvendelsene, selv om dette går ut over opprinnelig prosjekt/fokus. Lavere spenningsnivå og distribusjonsnettet er like interessante som høyspent.

Utfordring: områdekonsesjonene for distribusjonsnettet er utenfor Miljødirektoratets myndighet, mens konsekvensene, spesielt i sum, er viktige for Miljødirektoratet i forhold til miljøkonsekvenser. LCP er en positiv overraskelse. «Linjene som forsvant» - telegraf/telefonlinjene drepte mye fugl. Disse har forsvunnet, men er det mulig å dokumentere effekten av at disse forsvant. En studie på dette ville vært interessant.

Vassdrags- og energidirekoratet – Håvar Røstad

Konsesjonsbehandling en balansekunst som skal ivareta mange forhold: klimaendringer gir nye utfordringer på løpende bånd. Stor utfordringer å skulle samle kunnskap for å møte disse.

Fugl – det viktigste temaet. Herunder hotspots – vanskelig å vurdere tiltak på spesifikke områder, men viktig å identifisere hotspots og tiltak knyttet til dette. Heller enn å lete etter generelle tiltak bør det være et mål å kunne gjenkjenne hotspots og så iverksette spesifikke tiltak.

Bestandseffekter – ulikt mellom arter, men er det mulig å gjøre noe med? Skal man tenke bestand eller høy dødelighet for enkelte områder for enkelte arter. Har det en bestandseffekt? Her mangler undersøkelser. Effekt av restriksjoner i anleggsperioden – har tiltakene NVE pålegger i forhold til f.eks. hekkende fugl og rovfugl effekt? Dokumentasjon mangler.

Elektrokusjon – sittepinnen for hubro er godt eksempel + sittehindre på mastetraversene. Behov for gode, enkle og billige tiltak. Viktigere å tenke på elektrokusjon enn kollisjon da det er lettere å finne avbøtende tiltak. Kollisjon – fugleavvisere: har dette effekt reelt sett?

Skogrydding – hva er kumulative effekter/samlet belastning? Hva betyr fragmentering av landskapet? Hvordan kan dette eventuelt utnyttes positivt?

Leveringssikkerhet – konsekvenser av vær og uvær – store konsekvenser for regionalnettet – hvilke hensyn må tas for å ivareta både leveringssikkerhet og naturmiljø?

Teknologi – Viktig å finne bedre løsninger: lengre spenn, smalere kraftgater - *Reduksjon i produksjonskostnader* (legitimerer økt innsats på tiltak). Mye skepsis blant utbyggere vedrørende relevansen for krav om tiltak – eksempel fettede liner som reduserer levetidskostnadene.

Statnett - Asgeir Vagnhildhaug

Statnett skal investere 5-7 mrd. per år i en tiårsperiode (bygging av nytt nett, oppgradering av aldrende nett, tilknytting av ny fornybar energi, spenningsoppgradering m.m.).

Fugl/miljøundersøkelser: Økt kunnskap om bestandseffekter viktig (jfr. undersøkelsen i Ogndalen). Gode for- og etterundersøkelser viktig – god metodikk taksering og bruk av referanseområder.
Kollisjon vs. elektrokusjon, jfr. hubro som har spesielt vern – her er mye ugjort, bl.a. i forhold til tiltak for anleggsperioden.

Fosenprosjektet – detaljplanleggingsfasen er i gang (miljø-, transport-, anleggsplan); som krever mer kunnskap om effekter av ulike framgangsmåter, slik som helikopter vs. bakketransport etc. Før- etter- og underveisundersøkelser. Spesielt sårbare områder og hotspots: trekkruter, topografi, miljøfaktorer.

Begrenset skogrydding – effekter av dette.

Duplex, triples, quadriplexledninger – økt kunnskap om forskjeller mht. synlighet og kollisjonsrisiko sammenlignet med simplex-ledninger mangler.

SINTEF – Audun Ruud

Samfunnsmessige utfordringer identifisert gjennom bl.a. SusGrid-prosjektet.

- Nettutviklingsregimer – Norge, Sverige, UK
- Allmenne holdninger og kunnskap
- Økonomi – regulering og kompensering
- Styringsutfordringer

Forslag til grep og praksis for nettutviklingsplaner – bærekraftig nettutvikling; ny kunnskap, bedre planverktøy; økonomiske forhold; prosesshåndbok. Nye behov; hva er egentlig behovet? LCP-metodikken m.m. - har den iboende forutsetning at man «trenger linja». Men trenger man linja? Det oppstår argumentproduksjon. Behovsavklaring – hva slags kunnskap er det behov for? Grunnleggende energisystemplanlegging: sammenhengen mellom teknologi – økologi – økonomi. Fokus på miljøkonsekvenser ikke kun miljøeffekter – miljøkonsekvenser er også et politisk aspekt. Lokal forankring: Involvering betyr ikke automatisk aksept. Forholdet mellom plannivåer og aktører – et koordineringsproblem. Tidsbruk/timing: Hvordan balanseres de tre nivåene i nettet – sentralnettet – regionalnettet – distribusjonsnettet – her er det ulike regimer på ulike nivåer.

Stikkord fra den videre diskusjonen:

ØAa: I SusGrid er det fortsatt tid/penger for å forfølge ulike retninger. Er det mulig å lage felles søknad som trekker på både SusGrid og OPTIPOL? OPTIPOL har gjort mye på miljøeffekter og verktøy mens SusGrid har jobbet overordnet og politisk. LCP forener disse sidene, men behov for ytterligere utvikling og kobling mot samfunn/politikk/økonomi. Det hjelper ikke med verdens beste LCP hvis det grunnleggende spørsmålet er om man skal bygge ut i det hele tatt? Har et slikt fellesskap livets rett fra brukernes side, eller skal man fortsette hver for seg?

RM: Viktig å ikke bare betrakte veien videre fra en overordnet sysnsvinkel, men også se på helt nye muligheter. Først fokusere på de viktigste temaene – før format bestemmes.

AR: Fare for at man går tilbake til tradisjonelle rammer og eksperttilnærminger.

KB: CEDREN en god plattform; tett samarbeid med brukerne er grunnleggende.

FH: «Return-on-investment» mulig tema for nytt prosjekt.

SGS: Prosesstid en begrenset ressurs; ofte et budsjett som sprekker på tid. Ta hensyn til dette i LCP-metodikken –slagside for metodikken at den krever mye dialog/brukerinvolvering. Dette må synliggjøres ift. ROI og effektivitet av LCP.

AR: LCP interessant. Må inn etter konseptstudie (må ha bestemt at det skal være en linje). Koble LCP på SusGrid innsikten. Mye produksjonsinteresser i CEDREN; må være mer aktive mot nettselskaper (jfr. FoU-avgiften for nettselskapene - mulige IPN-søknader.

Ad. effektstudier

SGS: Mangelfulle KU'er - mulighet for større FoU-ramme med en forskningsmessig forståelse av effekter for å få på plass il et større forskningsprosjekt.

HR: Viktig å forankre KU'er på forskningskunnskap – dvs. etablere egne FoU-prosjekter for effekter av utbygging.

AR: Sumvirkninger kodifisert i biomangfoldloven, men ikke håndtert i praksis i KU'er og hos forvaltningen (man vet faktisk ikke hvordan dette skal tolkes).

Ad. kraftledninger/kraftledningsgater

HR: Mål på sikt at distribusjonsnettet skal legges i jorda; sentral- og regionalnettet vil være luftliner også i fremtida.

ØAa: Parallelle problemstillinger mot friluftsliv og reiseliv. Kraftgater og tilførselsveier kan benyttes til friluftsliv.

SGS: Varsel om bredere ryddegater for lavere spenningsnivå; 22 kV basert på ekstremvær og fare for trefall etc.

HR: En aktuell debatt i NVE.

SS: Allmennhetens bruk av kraftgater må tas med i vurderingen – hva kan fremme positive holdninger?

HR: Hva er effektene av forsterkningsmekanismer med både fragmentering og bruk av kraftgater?

AR: Hva med nye materialer – komposittmaterialer og nye master?

SR: Komposittmaterialer muliggjør helikoptertransport fremfor båndgående bakkekjøretøy – mulig mindre inngrep i anleggsfasen. Er kraftgatene en mulighet og ikke kun trussel? Hvordan kan dette være en kilde til friluftsliv, biologisk mangfold etc.? (Fra elektrokusjon til utkikkspunkt for hubro).

TN: Hjemkraft i Sverige har brukt milliarder for å grave ned nettet. Hva er motivet - lønner det seg?

HR: Når man bygger nytt nett er nedgraving lønnsomt, men ikke for eksisterende nett der konsesjonen er gyldig.

AR: Ett virkemiddel er å justere nivået for KILE-kost – hvis kostnaden for ikke levert energi er høy nok vil investeringer for nedgraving av nettet betraktes i annet lys.

Ad. fugletrekk

HR: Vilkår må gjelde for alle –radar for spesialisert for generelle krav. Det har vært for lite definert hva vi faktisk skal bruke det til/se på. Hvis dette hadde vært tydeliggjort ville det være aktuelt å bruke penger på.

SGS: Fuglekartlegging er generelt sett for dårlig. For Miljødirektoratet er dette et generelt behov, men det må kunne dokumenteres at dette er reell problematikk ift. nettutbygging for deretter å begrunne et forskningsbehov.

SR: Hva slags type fugletrekk snakker vi om? Er det ikke en nasjonal oppgave å kartlegge store fugletrekk?

AR: Planavdelingen overført til KMD, ikke forankret i KLD. Er omorganiseringen av offentlig myndighet kunnskapsbasert?

RM: Radarovervåkning av fugletrekk kan kobles med meteorologiske og militære overvåkningssystemer.

KB: Hvordan lykkes med å få nye prosjekter i eksisterende NFR-programmer? Samspill og støtte fra NVE, MD, Statnett, Energi Norge m.fl. avgjørende.

SSt: NINA har egen radar på Smøla. Hvordan kan dette benyttes for å kartlegge andre hotspots i Norge? Opp til NINA i identifisere mulige gevinster fra radarbruk. Basert på eksisterende verktøy og databaser (digitale terrengmodeller) er det mulig å modellere/simulere hotspots for fugletrekk og kollisjoner/elektrokusjon?

SR: Vi har greid å identifisere feilfrekvenser på bakgrunn av fugl og kollisjoner. Dette gjelder spesielt for enkelte nett-kategorier og områder.

AR: Hvordan koble slike data mot KILE-kostnader - kvantifisering av kostnader? Bør ta dette direkte med nettselskapene.

Ad. samfunnsmessige utfordringer

AR: Viktig å se på nivå-spillet mellom ulike dimensjoner og aktører i prosessene. Energisystemtilnærming er sentralt.

RM: Sentralt med helhetlige behovsanalyser, jfr. sumvirkninger, samlet belastning. Ikke kun fokus på nett, men gjerne med dette som innfallsvinkling.

SGS: KU'er del av et nasjonalt system for beslutning og forvaltning, og det er ikke nødvendigvis tilstrekkelig å se dette kun innenfor energisektoren.

AR: Må balanseres mot kravet i utlysningen fra ENERGIX (som har energifokus).

MMH: Utfordring med hotspots i spesifikke områder med stor fugledød (kollisjon) som ikke nødvendigvis er dekket av områdekonsesjoner.

SR: Nylige branner kan knyttes til 22 kV-nettet. Ekstremvær kan føre til svikt i nettet og initierer/akselererer nedbrytning og øker stress på nettet. Dette i sammenheng med tørt vær kan føre direkte til branner og manglende energilevering.

MMH: Betydelige midler rettet mot tiltak, men også behov for grunnleggende kunnskap. Det går inflasjon i løsninger, jfr. alle variantene av ulike forgreiningsmaster. Hva er egentlig behovet, ikke kun fokus på tiltak?

KB: Vi er rimelig omforent om problemfokus, men det gjenstår arbeid med å sy sammen/integrere prosjektbeskrivelser. CEDREN har mye fokus på formidling. Er det aktuelt å lage en samlet «håndbok»? Er det interessant å arrangere en større avsluttende konferanse, jfr. BirdWind og CWW? Muligens arrangert av forvaltningen/industrien selv?

SR: Stor utfordring å implementere ny kunnskap og vedlikeholde kunnskap – kunnskap må gjøres veldig lett tilgjengelig!

BB: Burde flere involveres i debatten - engasjere flere interessenter utenfor «menigheten»?

KOJ: Mulig å lage en informasjonsvideo på viktige tema (jfr. Norsk Skogeierforening)? Lettere å formidle enn en rapport på 120 sider.

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NINA Rapport

Norsk institutt for naturforskning (NINA) er et nasjonalt og internasjonalt kompetansesenter innen naturforskning. Vår kompetanse utøves gjennom forskning, utredningsarbeid, overvåking og konsekvensutredninger.

NINAs primære aktivitet er å drive anvendt forskning. Stikkord for forskningen er kvalitet og relevans, samarbeid med andre institusjoner, tverrfaglighet og økosystemtilnærming. Offentlig forvaltning, næringsliv og industri samt Norges forskningsråd og EU er blant NINAs oppdragsgivere og finansieringskilder.

Virksomheten er hovedsakelig rettet mot forskning på natur og samfunn, og NINA leverer et bredt spekter av tjenester gjennom forskningsprosjekter, miljøovervåking, utredninger og rådgiving.

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