NINA Report 620

Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway (Bird-Wind)

Report on findings 2007-2010

Kjetil Bevanger, Finn Berntsen, Stig Clausen, Espen Lie Dahl, Øystein Flagstad, Arne Follestad, Duncan Halley, Frank Hanssen, Lars Johnsen, Pål Kvaløy, Pernille Lund-Hoel, Roel May, Torgeir Nygård, Hans Christian Pedersen, Ole Reitan, Eivin Røskaft, Yngve Steinheim, Bård Stokke, Roald Vang

CEDREN Centre for Environmental Design of Renewable Energy

Forskningsrådet Statkraft Norges vassdrags- og energidirektorat NVE EnergyNorway

NINA Norwegian Institute for Nature Research

Teamwork

Enthusiasm

Integrity

Quality

Cooperation and expertise for a sustainable future

NINA Publications

NINA Report (NINA Rapport)
This is a electronic series beginning in 2005, which replaces the earlier series NINA commissioned reports and NINA project reports. This will be NINA's usual form of reporting completed research, monitoring or review work to clients. In addition, the series will include much of the institute's other reporting, for example from seminars and conferences, results of internal research and review work and literature studies, etc. NINA report may also be issued in a second language where appropriate.

NINA Special Report (NINA Temahefte)
As the name suggests, special reports deal with special subjects. Special reports are produced as required and the series ranges widely: from systematic identification keys to information on important problem areas in society. NINA special reports are usually given a popular scientific form with more weight on illustrations than a NINA report.

NINA Factsheet (NINA Fakta)
Factsheets have as their goal to make NINA's research results quickly and easily accessible to the general public. The are sent to the press, civil society organisations, nature management at all levels, politicians, and other special interests. Fact sheets give a short presentation of some of our most important research themes.

Other publishing
In addition to reporting in NINA's own series, the institute's employees publish a large proportion of their scientific results in international journals, popular science books and magazines.

Norwegian Institute for Nature Research

Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway (Bird-Wind)

Report on findings 2007-2010

Kjetil Bevanger
Finn Berntsen
Stig Clausen
Espen Lie Dahl
Øystein Flagstad
Arne Follestad
Duncan Halley
Frank Hanssen
Lars Johnsen
Pål Kvaløy
Pernille Lund-Hoel
Roel May
Torgeir Nygård
Hans Christian Pedersen
Ole Reitan
Eivin Røskaft
Yngve Steinheim
Bård Stokke
Roald Vang

Bevanger, K., Berntsen, F., Clausen, S., Dahl, E.L., Flagstad, Ø. Follestad, A., Halley, D., Hanssen, F., Johnsen, L., Kvaløy, P., Lund-Hoel, P., May, R., Nygård, T., Pedersen, H.C., Reitan, O., Røskaft, E., Steinheim, Y., Stokke, B. & Vang, R. 2010. Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway (BirdWind). Report on findings 2007-2010. - NINA Report 620. 152 pp.

Trondheim, 31 December 2010

ISSN: 1504-3312
ISBN: 978-82-426-2198-6

AVAILABILITY
Open

PUBLICATION TYPE
Digital document (pdf)

EDITION
Kjetil Bevanger

QUALITY CONTROLLED BY
Signe Nybø

SIGNATURE OF RESPONSIBLE PERSON
Research director Signe Nybø (sign.)

CLIENT(S)
The Research Council of Norway (NFR), Statkraft, Energy Norway, The Directorate for Nature Management (DN), The Norwegian Water Resources and Energy Directorate (NVE)

CLIENTS' CONTACT PERSON(S)
Tor Arne Hafstad (NFR)
Bjørn Iuell (Statkraft)

COVER PICTURE
White-tailed eagle with satellite transmitter. Photo: Espen Lie Dahl

KEY WORDS
Wind power, radar, bird, mortality, GIS, white-tailed eagle (WTE), willow ptarmigan

NØKKELORD
Vindkraft, radar, fugl, dødelighet, GIS, havørn, lirype

Abstract

Bevanger, K., Berntsen, F., Clausen, S., Dahl, E.L., Flagstad, Ø. Follestad, A., Halley, D., Hanssen, F., Johnsen, L., Kvaløy, P., Lund-Hoel, P., May, R., Nygård, T., Pedersen, H.C., Reitan, O., Røskaft, E., Steinheim, Y., Stokke, B. & Vang, R. 2010. Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway (BirdWind). Report on findings 2007-2010. – NINA Report 620. 152 pp.

The BirdWind project (2007-2010) is now concluded. This report summarises the main findings. Several scientific papers are in the process of preparation for publication in international peer review journals; this report only provides a brief overview. The main project objective has been to study species-, site- and seasonal-specific bird mortality; and to identify vulnerable species and site-specific factors that should be considered to improve the basis for future pre- and post construction EIAs in connection with wind power-plant constructions. To reach these goals work packages and sub-projects have focused on behavioural and response studies at individual and population levels, for selected model species. The white-tailed eagle has been a focal species during the studies, as several fatalities were recorded in connection with the Smøla Wind-Power Plant (SWPP) even before the project started; the SWPP has been the main arena for project fieldwork. Modelling the WTE collision risk and making a WTE population model were important elements of the project activities. The development of methodologies and technical tools for data collection and mitigating measures has also been an important part of the project. For practical convenience the project was divided into eight subprojects focusing on 1) bird mortality, 2) willow ptarmigan, 3) breeding waders and smaller passerines, 4) white-tailed eagle, 5) bird radar, 6) mitigating technology, 7) data flow and storage systems and 8) GIS, visualization and terrain modelling. Results and preliminary conclusions related to each of these subtasks are reported.

Kjetil Bevanger (kjetil.bevanger@nina.no)
Finn Berntsen (finn.berntsen@nina.no)
Stig Clausen (stig.clausen@nina.no)
Espen Lie Dahl (espenlie.dahl@nina.no)
Øystein Flagstad (oystein.flagstad@nina.no)
Arne Follestad (arne.follestad@nina.no)
Duncan Halley (duncan.halley@nina.no)
Frank Hanssen (frank.hanssen@nina.no)
Lars Johnsen (lars.johnsen@sintef.no)
Pål Kvaløy (pal.kvaloy@nina.no)
Pernille Lund-Hoel (pernillelundhoel@gmail.com)
Roel May (roel.may@nina.no)
Torgeir Nygård (torgeir.nygard@nina.no)
Hans Christian Pedersen (hans.pedersen@nina.no)
Ole Reitan (ole.reitan@nina.no)
Eivin Røskaft (eivin.roskaft@bio.ntnu.no)
Yngve Steinheim (yngve.steinheim@sintef.no)
Bård Stokke (bard.stokke@bio.ntnu.no)
Roald Vang (roald.vang@nina.no)

Sammendrag

Bevanger, K., Berntsen, F., Clausen, S., Dahl, E.L., Flagstad, Ø. Follestad, A., Halley, D., Hanssen, F., Johnsen, L., Kvaløy, P., Lund-Hoel, P., May, R., Nygård, T., Pedersen, H.C., Reitan, O., Røskaft, E., Steinheim, Y., Stokke, B. & Vang, R. 2010. ”Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway” (BirdWind). Aktiviteter 2007-2010. – NINA Rapport 620. 152 s.

BirdWind prosjektet (2007-2010) er nå avsluttet, og denne rapporten inneholder en kortfattet oppsummering av de viktigste resultatene. Flere vitenskapelige artikler er i ferd med og ferdigstilles for publiseres i internasjonale, vitenskapelige tidsskrift. Hovedmålsettingen med prosjektet har vært å studere arts-, steds og årstidsspesifikk dødelighet hos fugl samt identifisere sårbare arter og stedsspesifikke faktorer som bør vektlegges for å bedre grunnlaget for for- og etterundersøkelser når nye vindkraftverk skal etableres. For å nå disse målsettingene har de ulike arbeidspakkene i prosjektet fokusert på atferds- og responsstudier både på individ- og bestandsnivå hos utvalgte modellarter. Havørn har stått sentralt i prosjektet ettersom flere drepte ørner ble rapportert fra vindkraftverket på Smøla allerede før prosjektet ble igangsatt, og det var derfor naturlig at det meste av studiene ble lagt hit. Modellering av kollisjonsrisiko hos havørn, samt utarbeidelse av en bestandsmodell for havørn har følgelig vært en viktig del av arbeidet. Metodeutvikling og utvikling av effektive redskaper til datainnsamling og avbøtende tiltak har også vært spesielt fokusert. Av praktiske hensyn har prosjektet vært delt inn i åtte underprosjekt som har vært konsentrert om 1) dødelighet hos fugl, 2) smølalirype, 3) hekkende vadefugler og mindre spurvefugl, 4) havørn, 5) fugleradar, 6) teknologi knyttet til avbøtende tiltak, 7) dataflyt og datalagringssystemer, 8) GIS, visualisering og terrengmodellering. Resultater og foreløpige konklusjoner i tilknytning til hvert av disse delprosjektene rapporteres her.

Kjetil Bevanger (kjetil.bevanger@nina.no)
Finn Berntsen (finn.berntsen@nina.no)
Stig Clausen (stig.clausen@nina.no)
Espen Lie Dahl (espenlie.dahl@nina.no)
Øystein Flagstad (oystein.flagstad@nina.no)
Arne Follestad (arne.follestad@nina.no)
Duncan Halley (duncan.halley@nina.no)
Frank Hanssen (frank.hanssen@nina.no)
Lars Johnsen (lars.johnsen@sintef.no)
Pål Kvaløy (pal.kvaloy@nina.no)
Pernille Lund-Hoel (pernillelundhoel@gmail.com)
Roel May (roel.may@nina.no)
Torgeir Nygård (torgeir.nygard@nina.no)
Hans Christian Pedersen (hans.pedersen@nina.no)
Ole Reitan (ole.reitan@nina.no)
Eivin Røskaft (eivin.roskaft@bio.ntnu.no)
Yngve Steinheim (yngve.steinheim@sintef.no)
Bård Stokke (bard.stokke@bio.ntnu.no)
Roald Vang (roald.vang@nina.no)

Contents

Foreword

In June 2006 NINA submitted a research project application (for the period 2007-2010), to the Research Council of Norway (NFR) named "*Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway*" (a so-called KMB project, i.e. a capacity-building project with industry/user participation). The Norwegian Water Resources and Energy Directorate (NVE), the Norwegian Electricity Industry Association (Energy Norway), and Statkraft at the outset committed themselves to contribute an annual economic support to the project (at least 20% of the total costs). Additionally Statkraft have given a considerably economic support for, among other things, the purchase of a bird-radar system which became operative in March 2008. During the course of 2007-2010, the environmental management authorities (The Ministry of Environment and The Directorate for Nature Management) and NVE have contributed economically both to existing and new research modules under the project umbrella. In spring 2008 NINA was invited by NFR to apply for extra funding for the project and received in September an extra grant of 1.5 million NOK for "*Data flow and storing, visualisation and modelling*". In late 2008 and early 2009 Statkraft and NINA discussed the possibilities to raise money for a PhD student to model the future white-tailed eagle population development based on reproduction and mortality data. An agreement was signed where the total costs of 2.5 million NOK were divided between NINA and Statkraft with 1 and 1.5 million NOK respectively. The position is held for four years (2009-2012). In spring 2009 the project became an integrated part of CEDREN – i.e. the *Centre for environmental design of renewable energy*, one of eight centres for Environment-friendly Energy Research (CEER) in Norway. CEDREN is a consortium with SINTEF, NTNU and NINA as key institutions. Although 2010 formally is the last operational year for BirdWind, some of the activities will proceed into 2011. However, this report is summarizing the 2007-2010 activities, and is the final NINA/CEDREN Report from the project. As the project has been publishing an annual report ever since 2007, these reports should be approached to find details on the project evolution. The rest of the reporting will have the form of publications in scientific journals.

We want to express our sincere thanks to the involved staff in Statkraft, Energy Norway, DN and NVE for a very positive and fruitful cooperation, as well as to several people from the local community on Smøla. The help, enthusiasm and interest you have exposed have been an inspiration to all of us! In particular we want to thank our project advisors, Mark Desholm (National Environmental Research Institute - NERI), Olle Håstad (University of Uppsala) and Rowena Langston (RSPB) for fruitful discussions and assistance throughout the project.

Trondheim, 31 December 2010

Kjetil Bevanger
Project leader

1 Introduction

In Norway the energy authorities, the Ministry of Oil and Energy (OED) and the Norwegian Water Resources and Energy Directorate (NVE), are responsible for the licensing of wind-power plants, i.e. to say yes or no to applications from the energy industry. The same authorities have the responsibility of deciding on what is good practice in reconciling wind-power generation with environmental concerns, by specifying in the concession documents on pre- and post-construction monitoring - e.g. on birdlife impacts. Unlike many countries, the environmental authorities - the Ministry of Environment (MD) and the Directorate for Nature Management (DN) - do not have the authority to dictate the content or scope of the EIA, or of the pre- nor post-construction monitoring programme. It is not uncommon that these authorities have differing views regarding what is “good practice”, and that the environmental authorities would like to have a more solid documentation regarding possible environmental impacts.

The construction of the Smøla Wind-Power Plant (SWPP) initiated an interesting debate regarding the economic responsibility for obtaining environmental impact data. As wind power generation was quite a new activity in Norway only ten years ago, no one had thoroughly defined the content of “good or best practice” in connection to it. Vague guidelines, together with absence of national experience regarding how a wind-power plant could affect the Norwegian environment, generated an interesting debate among the actors – the energy industry and the energy and environmental authorities. The industry claimed that it was the responsibility of the public authorities to obtain basic data, and to pay for basic research to make a better platform for how to design an EIA study as well as pre- and post-construction studies.

As it was known from international studies that bird mortality has been a major problem associated with some wind-power plants, the ornithological impacts became a focal issue. When NINA in 2006 designed the BirdWind application to the NFR, it was as a result welcomed and supported by both the energy industry and the management authorities. This support was probably an important reason for the success of the application within the framework of the Research Council of Norway’s RENERGI Programme, a Programme which defines “environmental issues” from the “brown” sector’s perspective, and not the “green” perspective focusing on ecological issues.

1.1 Project history

Since 1999 NINA has conducted research and EIA activities related to projects on wind-power generation and birds (with special focus on the white-tailed eagle) on Smøla (**Appendix 1**). In short the project history (2007-2010) is:

- **2007:** NINA was informed by NFR in late December 2006 that the BirdWind application was funded. On a meeting in Trondheim at the NINA Head Office January 4 2007, with Statkraft, SINTEF and NINA present, the short- and long-term activities and additional funding from Statkraft, were discussed. The meeting concluded, among other things, that Statkraft would fund a pilot study focusing the advantages/disadvantages of avian radar technology, together with possible technical solutions to mitigate the white-tailed eagle (WTE) collision hazard and what could be useful for basic data recording, involving audio and visual stimuli. This work was primarily carried out by SINTEF and the final reports from SINTEF were sent to Statkraft on 24th April 2007. On the 15th of May 2007 NINA sent a note to Statkraft where, *inter alia,* an economic guarantee was requested to obtain an avian radar laboratory in accordance with the recommendation of the SINTEF report. In June 2007 NINA and Statkraft signed an agreement (Contract 45000022770) that Statkraft should contribute with 9.610 million NOK within the project period (2007-2010). The funding was earmarked activities described in the agreement document.
- **2008:** NINA signed a contract with DeTect and received a Merlin avian radar in March. In spring 2008 NINA was invited by NFR to apply for extra funding for the project and received an

extra grant of 1.5 million NOK for "*Data flow and storing, visualisation and modelling*" in September. Statkraft promised another 1 million NOK for support to the avian radar research activities.

- **2009:** In late 2008 and early 2009 Statkraft and NINA discussed the possibilities to raise money for a PhD student to model the future WTE population development based on reproduction and mortality data. An agreement was signed where the total costs of 2.5 million NOK were divided between NINA and Statkraft with 1 and 1.5 million NOK respectively. The position is held for four years (2009-2012).
- In spring 2009 the project was integrated in CEDREN – i.e. the *Centre for Environmental Design of Renewable Energy*. CEDREN is one of eight centres for Environment-friendly Energy Research (CEER) in Norway. The establishment of the CEER scheme is a direct response to the broad-based agreement on Norway's climate policy in the Norwegian Parliament (Stortinget), reached early in 2008, and the adoption of the national R&D strategy *Energi21.* Norway has decided to earmark at least 100 million NOK per year to the CEER initiative. For the Norwegian research institutions the application process started in May 2008 and a final decision on the winners was taken by the Research Council Executive Board on 28 January 2009, and the official announcement was made by the Minister of Oil and Energy February 4 2009. CEDREN is a consortium with SINTEF, NTNU and NINA as key institutions. SINTEF is responsible for co-ordinating the CEDREN activities and the basic funding comes from NFR, together with users like Statkraft, Energy Norway, NVE etc. Thus the basic activities within CEDREN are based on the ongoing activities in BirdWind and 6 other KMB projects. The overall objective of CEDREN is to *develop and disseminate effective design solutions for renewable energy production that take adequate account of environmental and societal issues, both locally and globally*.

1.2 The challenge of basic and applied research integration

The BirdWind project proposal was sent to the RENERGI Programme as a so-called KMB project. KMB projects are capacity-building projects with industry/user participation, where the industry partners commit themselves to contribute at least 20% of the total project cost, while the remaining costs are covered by NFR. It is always a challenge to integrate the differing interests of the KMB-project owners, – NFR expecting basic research, and industry more applied research. In the BirdWind project the energy- and environmental management authorities have also been partners, with their own needs and problem-solving approaches. The obvious challenges within KMB projects in general are connected to the expected output – NFR being positive to basic research and international publications in peer review journals, while industry and management authorities in general expect answers to be applicable for solving problems within a relatively short period of time.

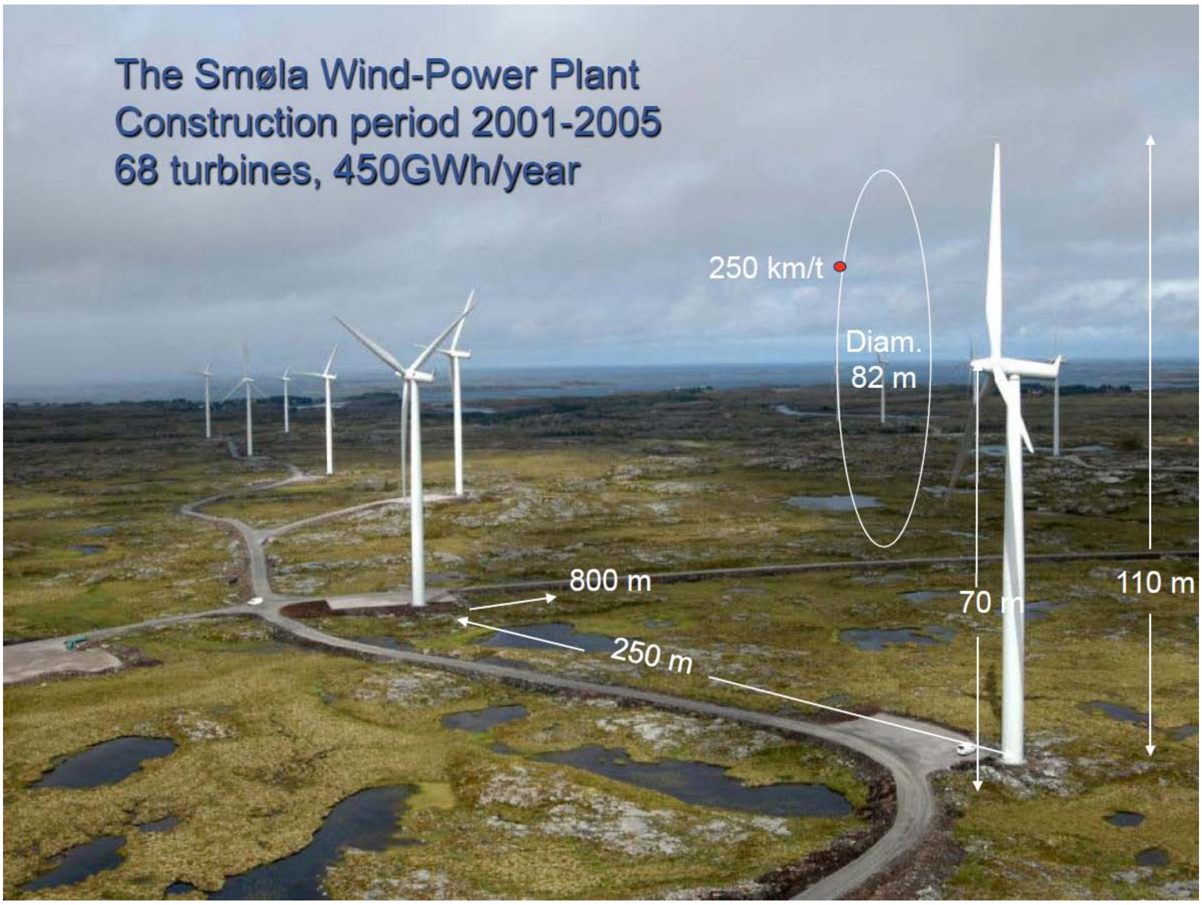
The BirdWind project has been no exception with respect to differing expectations for the outcomes of the money spent. It has, however, been a very positive dialogue between the project owners throughout the project, and mutual respect for differing views and priories. The main arena for discussions has been the project Annual Meeting where all projects owners (except NFR) have been present together with the involved scientists. The 2010 meeting was arranged on Smøla in March as the fourth and last Annual Meeting in BirdWind (**Appendix 1**).

1.3 Some remaining questions

Several important questions remain unanswered. It was realised from quite an early stage that some of the ambitious goals addressed at the onset would not be reached within a four year timeframe. Planning how to proceed with some of the BirdWind activities has therefore been a topic for some time. In September 2010 a new project application was sent to NFR (BirdWind2 – *Mitigation measures and tools to reduce bird-associated conflicts in space and time for onshore and offshore wind-power plants*). Unfortunately the application was unsuccessful. However, we have received verbal support from Statkraft and other BirdWind partners indicating that it is desirable for CEDREN/NINA to continue some of the research activities in BirdWind. In particular, the focus in a possible continuation will be issues related to mitigating measures, e.g. how to reduce the collision hazard for the WTE and the willow ptarmigan, although one possible conclusion could still be a “no cure scenario”; i.e. accepting a certain number of casualties at wind-power plants. Increased experience of the use of bird radars as a tool for improved EIA analyses is another important issue for reaching the goal of reliably determining places where the environmental impacts of wind power do not exceed acceptable levels. In addition to the overall conclusions following each sub-project chapter, some important remaining questions are outlined.

1.4 The Smøla Wind-Power Plant – some facts

The wind-power plant on the island of Smøla (SWPP), in the county of Møre og Romsdal is still the largest in Norway. The 68 turbines are located in an open, flat terrain, 10-40 m above the sea level. The SWPP was constructed in two phases between 2001 and 2005. The 20 turbines built in phase one have an installed capacity of 2 MW, while the 48 turbines in phase two have an installed capacity of 2.3 MW each, giving a total of 150 MW. The average, annual production is 450 GWh. The turbines initiate an electricity production at a wind speed of 3 m/sec. and are stopped at 25 m/sec. to avoid technical damage. The turbines have an optimum production at a wind speed of 13 m/sec. The hub height of all turbines is 70 m above the ground, and the rotor diameter of the 2 and 2.3 MW turbines are 76.0 and 82.4 m respectively with a corresponding rotor-swept area of 4500 and 5300 m^2.



1.5 CWW2011

BirdWind is approaching its completion; and in 2011 the Annual Meeting will be replaced by an international conference with a focus on selected topics reflecting the project activities. For further information follow this link: www.cww2011.nina.no.

Conference on
Wind energy and
Wildlife impacts

May 2-5 2011, Trondheim, Norway

The first large international conference on wind energy and wildlife impacts

Sessions

- Site selection, EIA, and pre- and post-construction studies
- Species-specific vulnerability and population effects
- Behavioural and spatial responses of wildlife
- Collision risk modelling
- Tools, methods and technology
- Mitigation and compensation
- Future challenges: offshore and onshore

Time schedule/important dates

01.12.2010 Deadline for submission of abstracts
01.02.2011 Closing registration

Keynote/invited speakers/session convenors

Tormod Schei
Dr. Kjetil Bevanger
Michael O'Briain
Dr. Rowena Langston
Dr. Mark Desholm
Prof. Dr. Thomas Kunz
Dr. Elisabeth Masden
Prof. Dr. Johann Köppel
Dr. Edward Arnett
Dr. Shawn Smallwood
Dr. Andrew Gill
Dr. Roel May

www.cww2011.nina.no

Partners

2 Bird mortality

Subproject responsibility: Ole Reitan

Objective: To document wind turbine induced bird mortality, including
- identifying species-specific factors trigging high collision risk and possible causes of death
- searches for dead birds and bias testing
- estimating collision rates

2.1 Principles and methodological challenges

Birds visiting or living in the SWPP area are occasionally killed when hit by the turbine blades or colliding with the towers. The turbulence caused by the rotating blades may also be a cause of death, although this has not been documented. To estimate the real mortality rates the initial step is to search for, and locate collision victims. Several factors affect the possibilities to achieve reliable estimates of collision rates. E.g. in most studies collision victims have been recorded within 100 m from the turbine tower. On Smøla, some WTE collision victims have been found more than 100 m from the tower. The area covered constitutes approximately 31,400 m² around each turbine. Hence, the searching effort is in itself a very labour intensive activity. Due to scavengers some of the victims may be foraged, or transported out of the searched area. The time period between a collision and the search may therefore be crucial for the possibility to find a victim.

The probability of observing a collision or a bird being trapped by the turbine-induced turbulence is very small. If say we had a total of 100 collisions in the SWPP area each year that would give an average of only 2 dead birds each week. Nevertheless, some few direct observations of WTEs being hit by the rotor blade have been made, one of these was 12 May 2010 at turbine number 42 (Geir Wang, Statkraft). In 2009 (4 March) a collision was observed by the sound when the rotor blade hit an eagle at turbine number 9, and the observer could see the corpse falling to the ground (Finn Eide pers. comm.). A WTE yet warm was found 11 April 2010 at turbine number 1 (Asbjørn Dyrnes, Statkraft pers. comm.), and this collision could be verified by avian radar recordings. On 13 March 2008 a WTE was found at turbine number 67. The bird had been cut into two pieces and streaks of blood could easily be seen on one of the rotor blades. For willow ptarmigan at least one bird was found close to a turbine base on Hitra and with both blood and feathers on the tower (Frode Vitsø pers. comm.).

2.2 Search methods and the search regimes

Searches for dead birds near the turbines have been carried out since January 2006, and from 1 August 2006 by especially trained dogs. Thus, the period with “dog searches” has been more than four years, and approximately 5700 turbine searches have been conducted. In total more than 100 birds were found dead during the dog searches, and a total of 45 dead birds were found by others (other project personnel of BirdWind, SWPP staff or general public) since the start of the first turbines in 2002. All live birds (except small passerines) have been recorded during the fieldwork as well (i.e. more than 2000 hours of observations of birds in the SWPP).

In principle there are two main searching methods, the first involving one or more observers walking in a more or less fixed pattern searching visually for dead birds. Most searches in the vicinity of the wind turbines, towers and power lines have been variants of this method (e.g. Smallwood & Thelander 2008). The other method is the use of one or more dogs. A dog searches mainly by the olfactory sense, and therefore covers an area determined by movements of scent in the air. As a dog only needs a few molecules to respond to a scent, it is expected to be more efficient than visual searches by man. The dog has to respond to the scent from dead bird carcasses. For searches in the SWPP a riesenschnauzer, Luna, was trained to have a search image of groups of feathers and to indicate a dead bird or feathers by lying down at the object. It is important to emphasize that this is different from searching and finding live birds, but Luna was earlier trained to search for humans and therefore she responds also to breathing individuals, including live birds. Additionally a slow running behaviour during the searches was reinforced in Luna, to increase the possibility to be exposed for scent during the searches. Luna was trained in a three-month period before the first turbine search.

A briard - Solan - was also trained to find dead birds, by reinforcing when he found dead birds and feathers in the first searches. Solan was earlier an authorized avalanche dog, and trained to find humans also on snowless ground. This included searching for different objects in defined fields. The converting of Solan to a dog searching for dead birds required several months. However, he has recorded both dead and injured birds nearly as efficient as Luna, though with poorer efficiency at finding feather groups.

The dog searching method has been evaluated by comparing the efficiency of the dog and dog handler in finding dead (or injured) birds. For each bird or bird remain found, also the finder was recorded. Overall the dogs were more efficient than the dog handler. Because the dog uses the olfactory sense, the wind direction had to be recorded at each turbine before deciding the search pattern. The most efficient search will be when the searching dog is directed at right angle to the wind direction. Therefore the searches were mainly conducted at a fixed pattern, only differing by the wind direction.

Of the 68 turbines in SWPP, 25 were randomly selected as primary “search turbines”, being searched once a week throughout the whole year. In addition all turbines were searched once a month in periods with higher collision risks (March-May). In total there have been 5698 turbine searches until 31 December 2010, with some annual (1 August - 31 July) variation (1214-1490). In addition to the searches in the SWPP, 24 weekly searches in connection to the 24 turbines at the Hitra Wind-Power Plant have been made (April-November 2009) in connection to an EIA study (Bevanger et al. 2010). For each recorded victim the GPS position was recorded together with several other relevant variables characterizing the carcass and the search.

2.3 Search results

2.3.1 White-tailed eagle

A total of 39 dead or injured WTEs have been recorded within the SWPP area (1 August 2005 - 31 December 2010). Of these 28 (72%) have been found during 2-2.5 months each spring between the beginning of March to the beginning of June, with the peak varying somewhat between years. In the autumn 7 (18%) dead/injured WTEs have been recorded (**Figure 1**). Since 1 August 2005 (operational start of the 48 turbines in stage 2) to 1 August 2010 on average 7.8 WTE have been recorded per year, i.e. 0.11 dead WTE/turbine/year. Of the 39 WTEs, 21 (54%) were adults (in their 6th calendar year or older). They have mainly been recorded in the spring or autumn. A total of 11 (28%) subadult (2 cy summer – 5 cy) birds have been recorded, mainly in spring, and 7 (18%) juveniles (less than one year old) in the autumn and their first spring (**Figure 2**).

The WTE victims show a distinct pattern also in space; 11 (28%) have been found in connection to 5 turbines in the northwest part of the SWPP, between numbers 21 and 26. Some of the turbines have been searched weekly with no recorded victims, e.g. numbers 27-29, 32, 34, 36, 40-41, 55, 2, 60 and 66. On Hitra 5 dead WTEs was recorded up to November 2009. The collisions were identified to have occurred in 2008 (3), 2006 (1) and 2007 (1) (or 2006). This gives an average of approximately 0.06 dead WTE per turbine per year, in comparison to 0.11 in the SWPP (Bevanger et al. 2010).

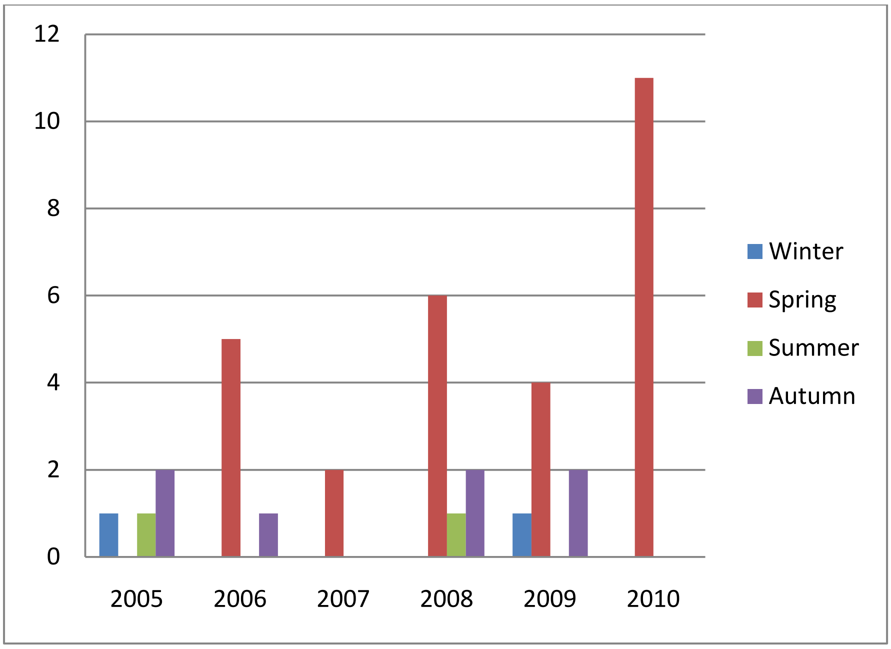


Figure 1. *Number of WTEs found (dead or injured) at the Smøla wind-power plant turbines (until 31 December 2010). The first was found in August 2005, however, regular searches were not initiated until 2006. Winter=December-February; Spring=March-May; Summer=June-August; Autumn=September-November*

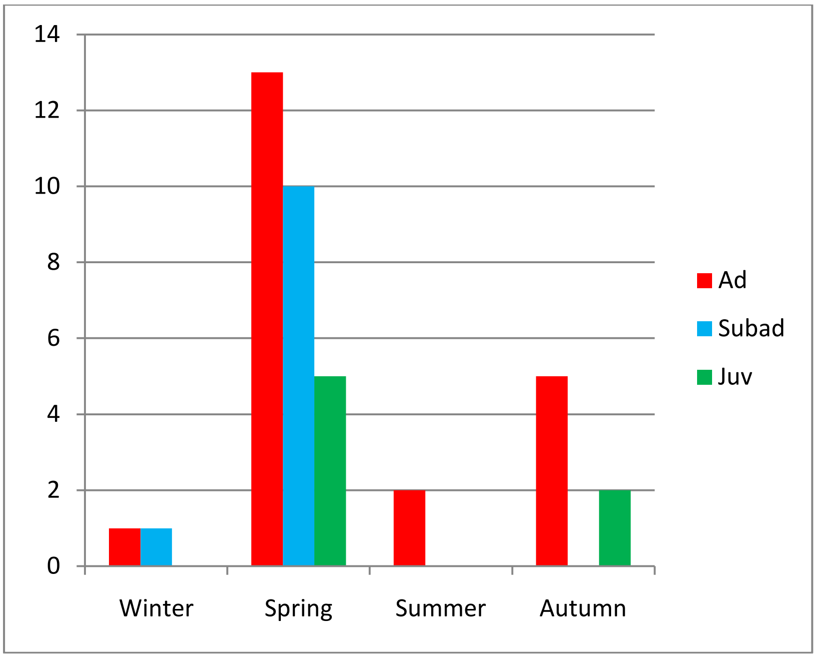


Figure 2. *Age distribution of white-tailed eagle victims from the Smøla wind-power plant. Ad=6cy+-birds, in their 6th calendar year or older; Juv=Birds in their first year; Subad=2cy summer-5cy birds, in their 2nd summer (from summer) through 5th calendar years. Se also legend in* ***Figure 1****.*

2.3.2 Willow ptarmigan

During the dog searching period, 82 dead willow ptarmigan were found inside or close to the SWPP area. Six ptarmigan were found more than 400 m from the peripheral turbines and have probably died due to other causes than the turbines. Two have collided with a car. The other 74 were found within the wind power-plant area, including birds found dead during the regular searches, radio-tagged birds (see 3.1.3) and occasionally observations of dead birds.

The majority of these 74 birds were recorded in March-June (42; 57%), 20 (27%) in November-January and the remaining distributed with 2-3 birds in each of the other months. Some of the birds recorded in March may have died in February (being unnoticed due to snow cover, particularly in 2010), but a majority had signs indicating a maximum of one or two weeks since death.

Of the 74 ptarmigan recorded in the SWPP area (excluded the two car-victims), 47 have been found within the search area (i.e. within a search radius of 100 m, some of these were also found by Statkraft staff or others; **Figure 3**). This area represents 31,400 m² per turbine, i.e. a total of 2.1 km² for all 68 turbines, i.e. only 12% of the total SWPP area. Of these 47 birds, 21 (45%) have been found within 30 m from a turbine (representing 3,140 m² per turbine, and for all turbines 1.2% of the whole power plant area) (**Figure 4**). This area (r=30 m) has more than 90% search efficiency for all bird species (Reitan et al. in prep.). However, the scavenging bias regarding ptarmigan seems to be high (documented by experiments and use of surveillance cameras; see below). The distance from the nearest turbine has been recorded for all dead birds, but so far it is unknown whether feather group-sites (body not present) are the true death site for these birds. Only one dead ptarmigan found more than 50 m from any turbine was found intact, and the death cause could not be determined. Such scavenged birds were classified as having unknown cause of death.

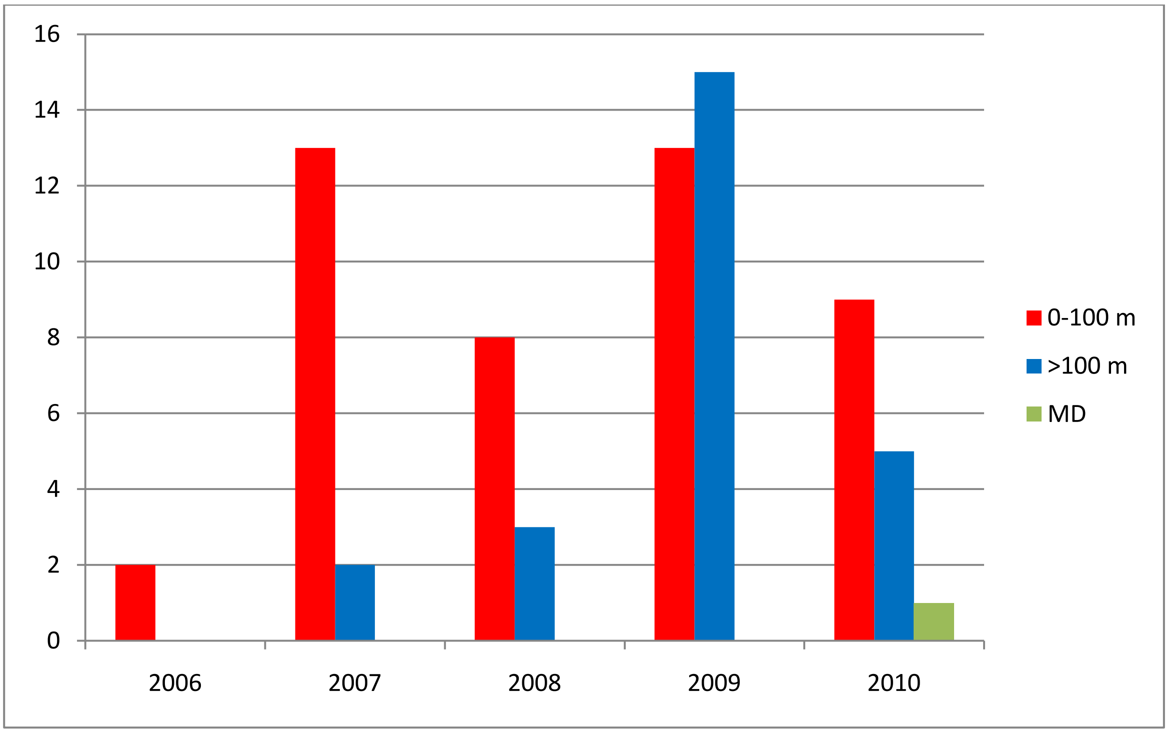


Figure 3. *Willow ptarmigan found dead in the Smøla wind-power plant area since August 2006, within and outside the searched area. There has been no regular searches covering areas >100 m from the turbines, and most of these remote victims are found occasionally or because of a radio transmitter from a radio tagged individual sending signals from the site. MD=unknown distance*.

Figure 4. *Dead willow ptarmigan and ptarmigan remains (inside blue ring) recorded near turbines; to the left an intact specimen (turbine number 26 – 5 May 2010) and a scavenged bird a few meters from the tower base (turbine number 32 – 21 March 2010).*

So far it has not been possible to verify how many of the total number of the willow ptarmigan recorded close to the turbines that have died due to flying into the tower, being hit by the rotor blade or died because of turbulence. However, it is interesting that seven recently died, whole ptarmigan, have been recorded within two-three meters from a turbine base. To find the real causes of death the following factors must be controlled: 1) The level of other death causes within the searched area; 2) The seasonal scavenging rate in the searched area, including the distance a dead bird is relocated; 3) The number of dead birds outside the searched area has been supposed to be very small, however, this must be verified (se also 2.6).

A few dead ptarmigan were recorded during the EIA study on Hitra in 2009. Statkraft personnel have found several dead, intact ptarmigan near turbines each year, the last one reported on 3 November 2010. At least one was found only a few meters from the tower base, with both blood and feathers on the tower nearby (Frode Vitsø, pers. comm.). Thus, there is no doubt that some ptarmigan are being killed because they collide with the turbine tower.

2.3.3 Other bird species

In total 65 individuals of other bird species were identified as collision victims in the SWPP area (**Table 1**). The total annual recordings have varied between 12 and 15 victims. The most common victim was the common snipe, mainly recorded between May and July. However, in 2010 – with many breeding wader pairs in the SWPP area – none were found. Another common wader victim was the golden plover (seven victims). Ten hooded crows have been recorded, but no raven, although ravens are regularly observed flying near and within the level of the rotor swept zone, while the hooded crow mainly flies closer to the ground. Both grey heron and greylag goose seem to be regular collision victims (**Table 1**).

About 20 species have been recorded with only one, two or three specimens (**Table 1**). This includes several occasional visitors living closer to the sea or in agricultural areas. Most of these victims have been recorded in March-May and August, suggesting that they have been birds on migration or on an irregular movement within the SWPP area.

Bats: One bat has been found near a turbine, a northern bat in August 2006. Smøla has a small population of northern bat, mainly living near buildings, forests and agricultural land on the eastern parts of the island.

Table 1. Dead birds (excluded white-tailed eagle and willow ptarmigan) recorded near the turbines in the Smøla wind-power plant area.

	>2005	2006	2007	2008	2009	2010	Total
Common snipe *Gallinago gallinago*		1	3	4	3		**11**
Hooded crow *Corvus corone*	1	1		2	5	1	**10**
Golden plover *Pluvialis apricaria*			2	2		3	**7**
Grey heron *Ardea cinerea*	1	1		1		1	**4**
Greylag goose *Anser anser*	1			2	1		**4**
Oystercatcher Haematopus ostralegus						3	**3**
Mallard *Anas platyrhynchos*			2		1		**3**
Gull indet. *Larus* spp.		2					**2**
Kittiwake *Rissa tridactyla*				1			**1**
Redshank Tringa totanus				1			**1**
Starling *Sturnus vulgaris*						1	**1**
Teal *Anas crecca*					1		**1**
Fieldfare *Turdus pilaris*		1					**1**
Golden eagle *Aquila chrysaetos*						1	**1**
Great black-backed gull *Larus maritimus*				1			**1**
Little auk *Alle alle*			1				**1**
Meadow pipit *Anthus pratensis*			1				**1**
Merlin *Falco columbarius*				1			**1**
Fulmar *Fulmarus glacialis*			1				**1**
Shoveler *Anas clypeata*		1					**1**
Northern wheatear *Oenanthe oenanthe*					1		**1**
Parrot crossbill *Loxia pytyopsittacus*					1		**1**
Red-breasted merganser *Mergus serrator*			1				**1**
Twite *Carduelis flavirostris*						1	**1**
Whooper swan *Cygnus cygnus*		1					**1**
Birds indet.							**0**
Birds total	**3**	**9**	**12**	**15**	**14**	**12**	**65**

2.4 Scavenger removal and search bias testing

Most biases are shown to be site-specific (Bevanger 1999), especially scavenger removal and habitat biases, thus the Smøla-specific factors must be estimated. There are few mammalian predators on Smøla, for instance no foxes or weasels. The American mink has, however, been observed within the SWPP area. The main possible scavengers include white-tailed- and golden eagles, gyrfalcons, hooded crows, ravens and large gulls.

To investigate these bias factors, experiments with placing dead birds and objects have been carried out (including ongoing experiments). All experiments lasted four weeks to cover the whole potential interval between turbine searches. This study has been carried out as part of the superior general mortality studies. In addition, due to the high number of dead willow ptarmigan found and the high mortality of radio-tagged birds, a more specific study of scavenger removal of willow ptarmigan has also been carried out (see 3.1.3). This is part of a master-thesis focusing on population effects of natural and turbine-induced mortality in the SWPP area.

2.4.1 Search bias

In this test greylag goose wings were placed at randomly selected distances and directions, at random selected turbines. The sequence of turbines was also randomly selected. In order to get information on a general pattern of the search bias, only goose wings were used. Series of 10, mainly unfrozen wings were placed at the randomly chosen sites. In short the result showed a distinct tendency to a decreasing efficiency with distance from the turbine (Reitan et al., in prep.), enabling correction estimates for dead birds at different distances from the turbines.

2.4.2 Scavenger removal bias

The experiments were based on cameras monitoring randomly placed bird carcasses in the searched area near the turbines (**Figure 5**), similar to those used in the Altamont Pass studies (Smallwood 2010). The total number of dead bird victims contemporary lying near the turbines at Smøla, is maximum 3-4 (based on the results in 2.3 and 2.5). Therefore the experiments are restricted to a maximum of five carcasses at the same time. To enable estimates for the possible intervals between the searches the experiments covered four weeks. Controls were made on a one week interval. If a carcass was removed the experiment was finalised. The carcasses were divided into four groups; large birds (>1 kg), small birds (<400g), and two groups of medium sized birds (400-1000g; birds with and without white or contrast colours in the plumage). Each carcass was characterized as either untouched, foraged on the site, moved (within the search area), or removed (from the search area). If a visit from a potential scavenger occurred, the species was recorded (if possible). The experiment started in October 2009, and all seasons are covered. Until 31 December 2010 a total of 39 dead birds have been monitored.

In short the results so far show that about 40% of the carcasses never were visited by scavengers within four weeks. The peak scavenging activity was the summer, with mainly in situ scavenging. It seems to be differences between large (>1kg) and small carcasses, and between white/contrastful birds and darker/grey/brown birds. The removal rate was highest during the first week (about 10% removed), and after 4 weeks about 20% was removed. Large carcasses, like eagles, goose and herons have been scavenged *in situ*, and only small parts have been removed. Most small bird carcasses have not been removed, and were scavenged *in situ*, both from insects and birds. Middle-sized dark carcasses were mostly not removed. Bird carcasses with white or contrastful colour patterns (including ptarmigan and adult gulls) had a higher removal rate than other carcass types, especially in the winter season. The mean scavenger removal rate for ptarmigan/gulls in the winter season is about 13% after one week and increasing to 44% after four weeks.

Figure 5. *A Cuddeback camera and a willow ptarmigan artificially placed for recording scavenger removal in the Smøla Wind-Power Plant area*. Photos: Ole Reitan.

2.4.2.1 Crows

The large carcasses were not moved from the site, and seem mainly to be foraged by corvids and insects. Especially during the summer season, both the hooded crow and the raven were foraging on the carcass at the site. In some instances they are observed to move parts of the carcass up to 10 m.

2.4.2.2 Eagles

Both the WTE and the golden eagle have been observed at carcasses in the SWPP area, e.g. the WTE have been seen both at dead willow ptarmigan and kittiwake. They have not yet been recorded by the cameras.

2.4.2.3 Unidentified species

Several scavenging incidents (dead bird removal) have been recorded leaving few signs of the scavenger. However, the removal pattern indicate that the majority of the removals are made by a scavenger having arrived in high speed (too high to trig the camera), and moved the carcass out of the search area. One possible predator could be the gyrfalcon, although this is a species normally focusing on live ptarmigan. The weight of these carcasses has been up to 1000g (herring gull). A carcass of 1600g (great black-backed gull) was moved 6 m (outside the range of the camera) and consumed there. Most of these artificial placed carcasses have been willow ptarmigan, but also other species with contrasting feather colours. This pattern has been observed between October and May, but not in the summer. The species seems to be the main scavenger on medium and small species in the SWPP area, and seems to have a search image focusing willow ptarmigan.

Observations of the gyrfalcon over the year support the “gyrfalcon theory”. All larger birds observed during the regular searches have been recorded (i.e. August 2006 - December 2010). The gyrfalcon is mainly observed between October and May, and only 2 cy or 3 cy individuals (based on photos of the birds), in accordance with general knowledge: While adult, breeding gyrfalcons are sedentary in their breeding areas during the whole winter many juveniles visit the coastal areas in winter (Bakken et al. 2003, Tømmeraas 2004, 2006). A majority of the observed gyrfalcons in the SWPP were sitting or flying in the neighbourhood of the turbines (few along the roads between the turbines), indicating that they searched for dead birds near the turbines. Carrion feeding in gyrfalcon is well documented and is explained as a necessary adaptation to cope with the large seasonal environmental changes in their breeding areas (Tømmeraas 1989).

2.4.2.4 Mammals and invertebrates

The only mammalian scavenger on Smøla is American mink. There have been some instances of supposed scavenging from American mink, mainly on small birds, and the species have been recorded several times on Cuddeback camera pictures. The species were recorded mainly at the northernmost and southernmost parts of the SWPP area. However it is regarded as minor importance as a scavenger in the project area. Shrews have also been recorded by the camera as scavenger *in situ*, especially in the winter 2010/2011.

Scavenging by insects leaves the carcass on the site where it initially fell down; insects may leave only feathers and bones of a medium-sized dead bird after one day of activity in the summer, and seem to be quite important as scavengers during this season The scavenging activity from insects and corvids result in a much higher scavenging rate in the summer. In addition to scavenging, the carcasses are decomposed by bacteria and fungi, leaving few remains after one year or two summer seasons depending on temperature. Few carcasses older than two years are possible to search, also by dogs.

2.5 Collision rate estimates

2.5.1 White-tailed eagle

Each turbine has been searched several times, and it is likely that all the carcass remains in the searched turbine areas have been located during the searches. No artificially placed dead bird >2kg has yet been removed from the search area, so scavenging bias is unlikely. The only bias which may be important is the crippling bias, birds surviving a collision and moving outside the search area before it dies. We have found two crippled eagles at the search turbines. As the primary search turbines cover 1/3 of all turbines, and search at each turbine occurs once a week, the extent of the crippling bias for WTE at the wind turbines is unknown.

2.5.2 Willow ptarmigan

Regarding willow ptarmigan being killed due to the wind turbines the two most likely explanations are that they are killed because they fly into the turbine towers or because they are loosing lift due to the turbine induced turbulence behind and dies because they are falling to the ground. The experiments with dead birds and cameras placed near turbines shows that birds with white plumage, like the willow ptarmigan, are frequently removed from the turbine searched area. Because of uncertainties about the “background level” of deaths (including predation) of ptarmigan, we have not yet estimated the annual numbers of turbine-caused victims.

2.5.3 Other bird species

The majority of the species recorded occur in very low numbers. Several of them are difficult to locate due to the dense heather vegetation, e.g. waders and passerines, although others may be easier to locate also to humans. However, these dead birds were recorded by the dog. A few of the “low number species” have a (partly) light-coloured plumage (kittiwake, other gull species, fulmar, oystercatcher and merganser), some are grey-coloured (grey heron, greylag goose, mallard), but the majority is species with a darker plumage. The white and grey species seem to follow the scavenging pattern of willow ptarmigan (see above), but the darker species seem to have a low scavenging rate. The mean (preliminary) search rate is 50%, indicating a total annual estimate of just above 30 victims for these “low number” species.

2.5.4 Bats

The one bat specimen recorded during the four year period searches have been carried out clearly indicate that bats are rare victims in the SWPP.

2.6 Preliminary conclusions and remaining questions

Conclusions:
1) Using especially trained dogs during the weekly searches in the SWPP have proved to be efficient and increased the accuracy of the collision rate estimates.
2) Search results:

- Since 2005 39 white-tailed eagles are recorded as collision victims at the turbines, on average 7.8 eagles each year, or 0.11 WTE/turbine/year.
- 28 (72%) of the WTEs have been found during 2-2.5 months each spring, and 7 (18%) in the autumn.
- 21 (54%) of the WTE victims are adults (mainly spring or autumn victims), 11 (28%) subadult birds (mainly spring victims), and 7 (18%) juveniles (mainly autumn and spring victims).

- The WTE victims show a distinct spatial distribution; 11 (28%) have been found in connection to 5 turbines in the northwest part of the SWPP, between number 21 and 26.
- For WTE, the only search bias which could be of some significance is the crippling bias, i.e. birds surviving a collision and moving outside the search area before dying.
- 74 willow ptarmigan have been found within the wind power-plant area, including birds found dead during the regular searches, tracking transmitters without movements and occasionally recordings of dead birds. Of these more than 50 are found during the searches. Between 10-15 are found each year, the majority in March-June (42; 57%), but also in November-January (20; 27%).
- About half the number of the willow ptarmigan victims has been located within the nearest 50 m from the turbine base.
- 65 individuals of other bird species have been identified as collision victims in the SWPP area, annually between 12 and 15 victims. The most common victims are the common snipe, golden plover, and hooded crow.

3) Bias testing:

- The dog search efficiency is decreasing with distance from the turbines enabling correction estimates for dead birds at different distances from the turbines.
- Dead birds are scavenged by several species and the scavenger removal bias varies with season and carcass appearance.

Remaining questions:

- Additional test experiments regarding the seasonal-specific scavenger bias have to be performed to obtain more reliable estimates on the total victim number in the SWPP.
- For some species it is necessary to get data on the mortality caused by other factors than wind turbines. This may be achieved by conducting seasonal searches in control areas outside the wind-power plant area. The least distance must be more than 500 m outside the outermost turbine rows.

3 Willow ptarmigan

Subproject responsibility: Hans Chr. Pedersen

Objectives: To study direct and indirect effects of wind turbines on willow ptarmigan behaviour, habitat selection, reproduction and survival in areas where wind-power plants are established or planned.

3.1 Introduction

In connection to the Environmental Impact Assessment before the development of the SWPP, the willow ptarmigan population was censused during May and August in 1999 (Follestad et al. 1999). An autumn census was continued by the landowners also in some years during 2000-2004. From 2005, an autumn census was carried out as part of a larger countrywide census programme (e.g. Solvang et al. 2005). From 2007 the willow ptarmigan population has been censused in spring and autumn in the SWPP area and in an adjacent control area (CA) outside the plant area (**Figure 6**). The census method used is line transects applying the programme DISTANCE (Buckland et al. 1993, 2001). The census gives information on density and reproduction (chick production) in both areas. In August 2007-2009 censuses of willow ptarmigan were also carried out on the adjacent island Hitra, within the Eldsfjellet wind-power plant area, and in the control area Skårfjellet. In both areas suitable willow ptarmigan habitat are very limited, and a modified version of DISTANCE was therefore used.

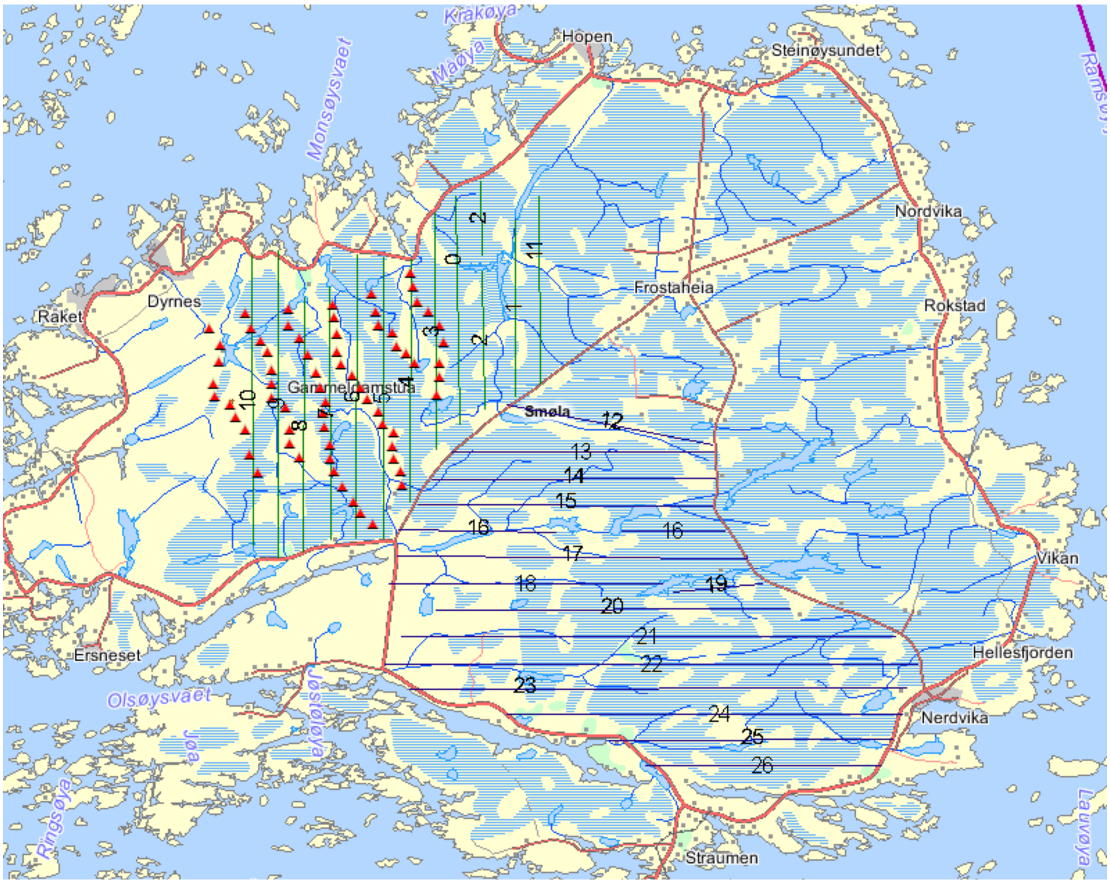


Figure 6. *Census lines on Smøla; lines within the wind-power plant area (0-11) and control area (12-26). Red triangles indicate the wind turbines.*

3.2 Results

3.2.1 Ptarmigan density and chick production

Preliminary analyses of ptarmigan density do not indicate any statistical differences between the two areas, neither in spring nor autumn from 2001 to 2010 (**Figure 7**). In both areas 2001 shows the highest density in spring and autumn; spring 7.7 birds/km^2 and 6.7 birds/km^2, SWPP area and CA respectively, autumn 19 birds/km^2 and 13 birds/km^2, SWPP and CA respectively. From 2005 to 2010, spring density has varied between 2.1-4.1 birds/km^2 and 2.6-4.1 birds/km^2 in SWPP area and CA respectively. Autumn density during the same period has varied between 4.0-9.0 birds/km^2 and 2.0-9.0 birds/km^2 in the SWPP area and the CA respectively (**Figure 7**). Although autumn density in the SWPP area seems to be more stable compared to the CA, the non-significant difference in density between the two areas to a great extent seems to be evened out in spring each year (**Figure 7**).

Annual chick production is one of the most important factors affecting autumn population density in willow ptarmigan. On Smøla the chick production has not been significantly different in the two areas during 2005-2010. Mean number of chicks/female has varied between 2.9-6.4 and 2.7-4.9 in the SWPP area and the CA respectively (**Figure 8**). Hence, chick production in general cannot explain the difference in autumn density between the two areas. However, in single years chick production contribute substantially to this difference as e.g. in August 2008 when chick production in the SWPP area was 6.4 chicks/female and only 2.7 in the CA. This was also the situation in autumn 2009, when the SWPP area and the CA had a chick production of 4.6 chicks/female and 2.9 chicks/female, respectively (**Figure 8**).

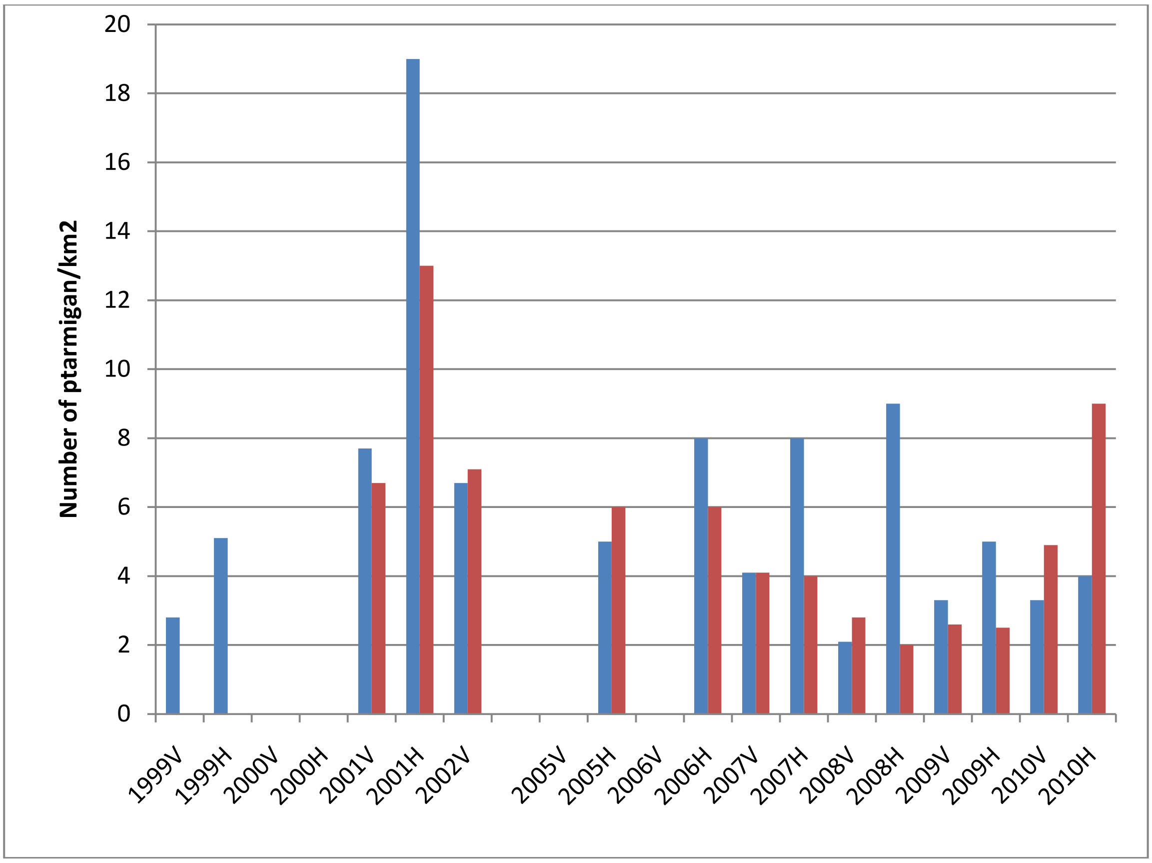


Figure 7. *Population density of willow ptarmigan (birds/km^2) in spring (V) and autumn*

(H) in the wind-power plant area (blue) and control area (red) in 1999-2010 on Smøla.

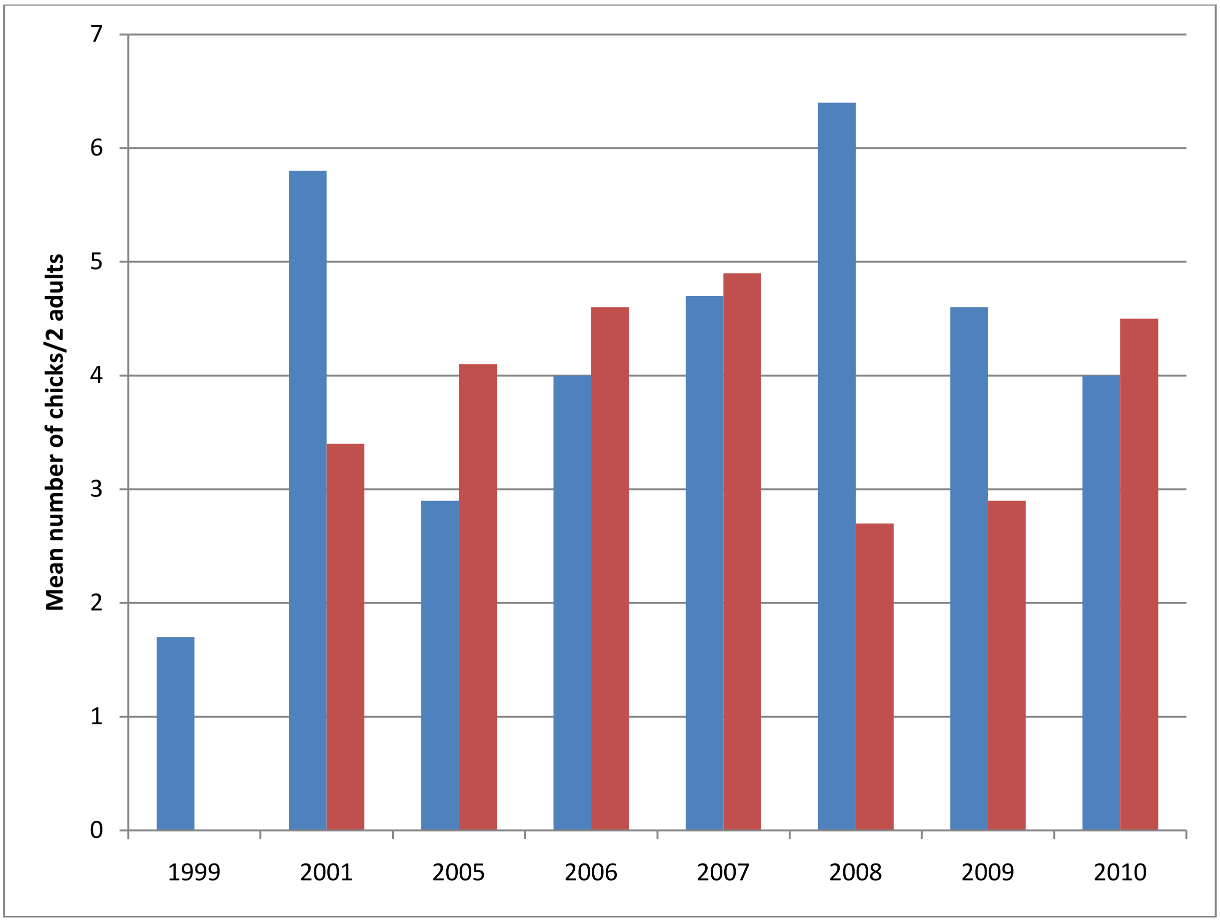


Figure 8. *Chick production expressed as mean number of chicks per female (2 adults) in August in the wind-power plant area (blue) and control area (red) during 1999-2010 on Smøla*.

3.2.2 Radio-telemetry studies

To collect data on habitat selection, movements, collision risks, avoidance behaviour, survival and general population dynamic parameters, willow ptarmigan have been radio-tagged in 2008-2010 (**Figure 9**). Traditional VHF-transmitters with mortality switch, necklace mount, 12g Holohill transmitters lasting for approximately 24 months have been used. Due to low population density and only occasional snow cover, a method using strong lights, dipnet and car has been used to catch birds. In total 34 willow ptarmigan were caught (19 males and 15 females).

All birds were caught inside the wind-power plant area. No trapping has been carried out in the control area, mainly due to lack of roads. The birds have been radio-tracked at irregular intervals and almost all birds, when found, have been located within the wind-power plant area, not far from where they were caught. However, during January-February 2010, when the SWPP area had unusually deep snow-cover, many of the birds moved out of the power-plant area to areas with available food.

Figure 9. *A Smøla willow ptarmigan equipped with radio-tag. Note the typical "salt and pepper" plumage typical of this sub-species during winter.* Photo: Sten Svartaas.

Except from one bird, where an exhausted battery was the likely reason for a missing signal, all radio-tagged ptarmigan are accounted for. In early December 2010, 5 radio-tagged ptarmigan were still alive in the SWPP area, which means that 28 birds have died since the radio-tagging started in January 2008. A Kaplan-Meier analysis of cumulative survival rates, show an exceptionally low annual survival (<30%). Unlike other willow ptarmigan populations most of the mortality is found during winter, from December throughout March (**Figure 10**).

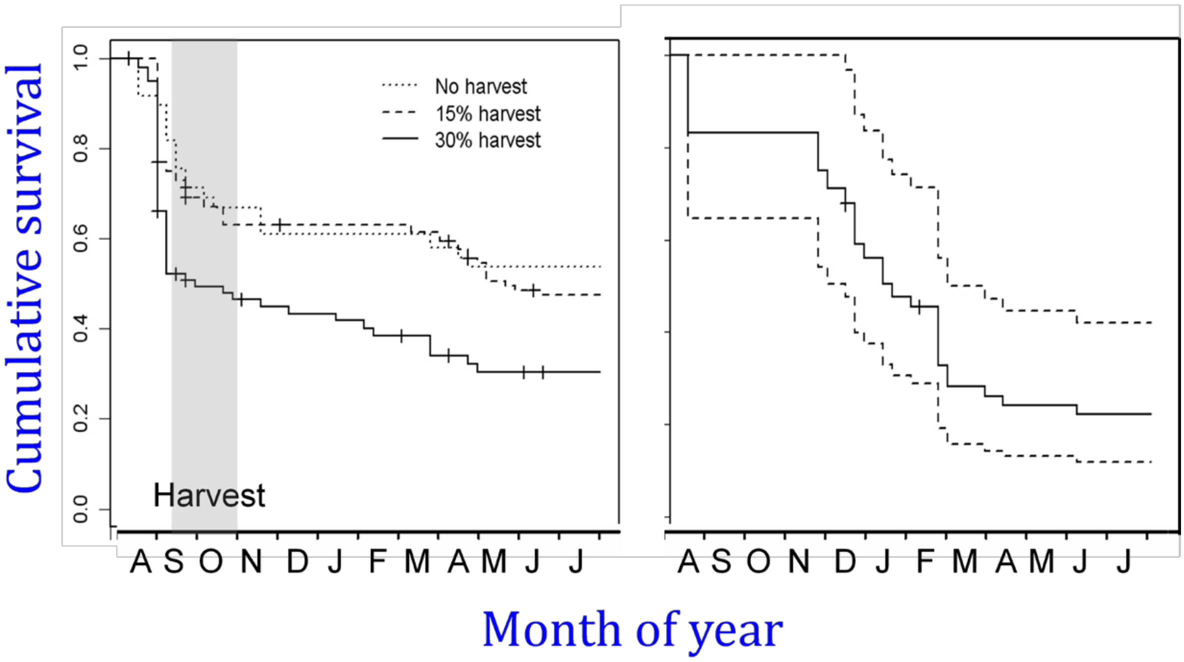


Figure 10 *Kaplan-Meier cumulative survival rates of willow ptarmigan on Smøla (right panel) compared to an inland population (left panel). In the inland population different harvest regimes are used, whereas no harvest is allowed on Smøla.*

3.2.3 Radio-telemetry and cause of death

Although a thorough analysis of mortality causes has yet not been carried out (see 2.3.2), most radio-tagged birds seem to be killed by avian predators and to a lesser extent through wind-turbine induced mortality (**Figure 11, 12**). To elucidate the question to what extent raptors feed on wind-turbine killed willow ptarmigan i.e. not killed by the raptor (natural mortality), a scavenger removal test was carried out in the SWPP area during two weeks of November 2010 (see also 2.4). Willow ptarmigan carcasses were laid out on every 3rd wind-turbine, in total 23 carcasses, approx 700-1000 m between each carcass. Ponce et al (2010) found no swamping effect putting out 5 carcasses/km, i.e. 200 m between carcasses, and Smallwood et al. (2010), found no swamping effect using 1-5 carcasses in a 2.5 km^2 wind-power plant area. Using 23 carcasses in SWPP (18 km^2), gives 1.3 carcasses/km^2. Each carcass was equipped with radio-transmitters similar to those used to radio-tag live willow ptarmigan. This allowed us to track removed carcasses and to describe and collect possible remains. In addition a camera was put up at each carcass.

During the two week period from 13–27 November 2010, in total 5 carcasses were removed from the original position; three by avian scavengers and two by American mink, whereas one additional carcass was eaten by a raven at the original position.

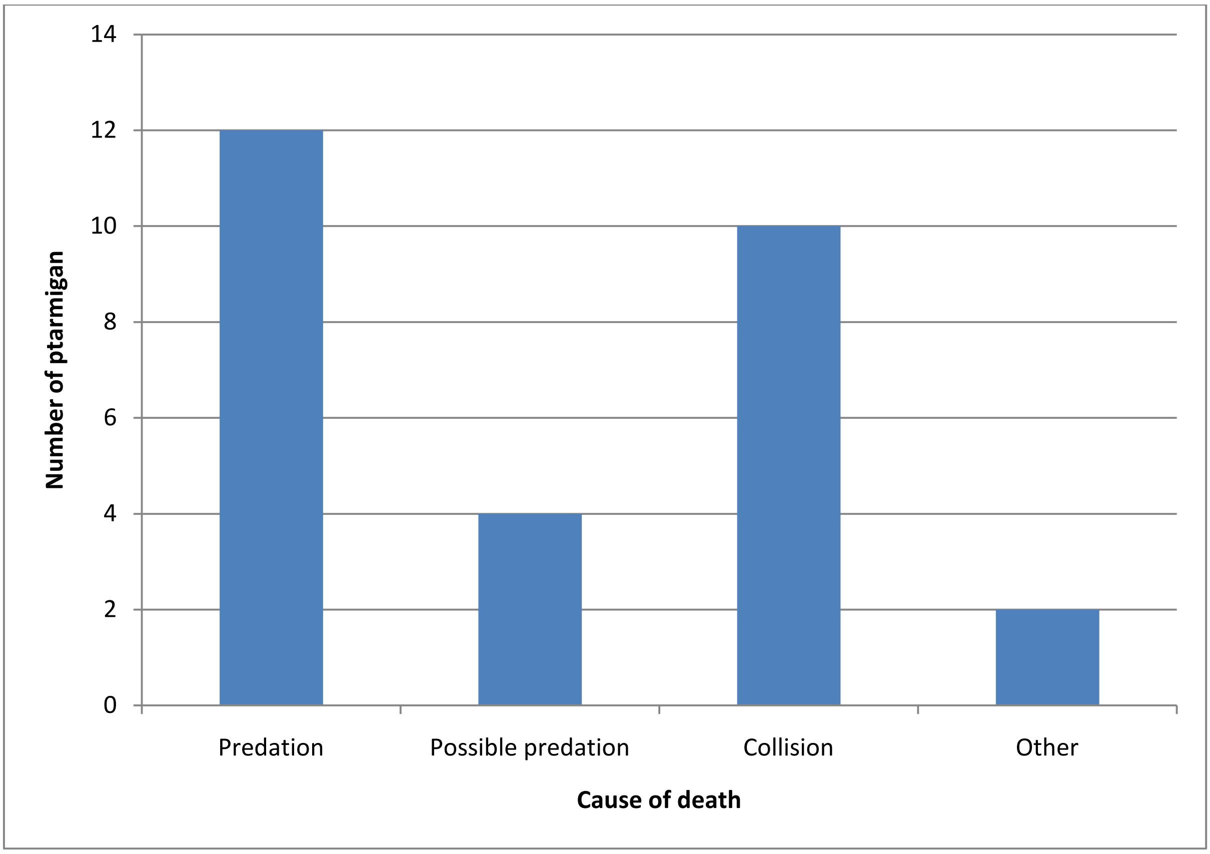


Figure 11. *Mortality causes of radio-tagged willow ptarmigan on Smøla.*

Figure 12. *A raven approaching a willow ptarmigan carcass laid out at a wind-turbine on Smøla. Five days after removal the radio-transmitter and some few willow ptarmigan feathers were found approximately 330 m away.*

In addition to the more common scavengers like corvids, it was also found during this trial that some of the willow ptarmigan carcasses were used by shrews. In fact, during a cold spell, shrews used the carcasses both as food and shelter; i.e. they lived inside the carcass.

3.3 Preliminary conclusions and remaining questions

The data collected throughout this study has only to a limited extent been analysed. Hence, the following conclusions are only preliminary.

Conclusions:

- Although there is some variation in density of the August population of willow ptarmigan, there is no consistent difference between the SWPP area and the nearby control area.
- Compared to other willow ptarmigan populations, chick production is reasonably good, and no difference is found between the SWPP area and the control area.
- Willow ptarmigan to a great extent use suitable habitats in SWPP area, and no evident avoidance behaviour is observed.
- Willow ptarmigan in the SWPP area have strong site tenacity and movements outside the SWPP area only happens during periods with deep snow cover making food inaccessible inside.
- Annual mortality of radio-tagged birds is much higher than in inland willow ptarmigan populations (>70% vs. 50%) and the mortality pattern is different from the pattern found in inland populations.

- Heavy winter mortality of radio-tagged birds seems to be caused by a combination of natural mortality and turbine-induced mortality.

Remaining questions:

This study has given new and unique information about this island population of Smøla willow ptarmigan. However, there are still many questions being unanswered. With respect to the special concern about possible negative effects of wind-power plants we need to answer questions regarding;

- The population effect of natural mortality compared to turbine-induced mortality.
- The importance of scavenging of dead willow ptarmigan, to better separate natural mortality from turbine-induced mortality.
- To sort out possible mitigating measures to reduce the collision hazard for willow ptarmigan.

4 Breeding waders and smaller passerines

Subproject responsibility: Duncan Halley

Objectives: To survey breeding populations of waders and small passerines in relation to wind turbines and assess any evidence for effects on bird distribution in relation to wind turbines.

4.1 Introduction

Ideally, distribution and populations of species of interest should be studied by monitoring both before and after construction (the BACI – before and after and control-impact – approach). This has not been possible on Smøla. Thus, the following strategy has been adopted:

1) A post-construction study on Smøla, investigating distribution in relation to turbine proximity, between areas within and on the edge of the turbine array, and comparing control areas of apparently similar landform and habitat characteristics on other parts of the island.
2) A pre- and post-construction study at Andmyran on Andøya, northern part of the Nordland County. A wind-power plant is planned for this site and planning permission has been given. It is for the moment unclear when the turbines will be constructed.
3) EIA pre-construction studies on Hitra in connection to the planned extension of the existing wind-power plant (Hitra I), i.e. the Hitra II wind-power plant.

4.2 The 2007 post-construction study on Smøla

4.2.1 Methods

Thirty 1 km transects were defined in the SWPP area: 10 on the western perimeter (Transect Area A) 10 in the central area (B), and 10 on the eastern perimeter (C). In addition, two control areas were set up outside the wind-power plant, 10 transects on Toppmyra in flat blanket bog terrain, similar to the eastern edge of the wind-power plant area (D), and 10 to the west of the power plant in broken moorland resembling the habitat found in the western power plant (E) (**Figure 13**). Transect lines in each block were 200 m apart. Each of the 5 blocks therefore consisted of 2 km^2 of terrain. Transects in the western control area were offset to avoid disturbing a breeding pair of WTE discovered while performing the first transect survey so that while the area was the same it was not arranged in a single block. The location of transect area B was also selected to avoid the nest sites of two pairs of WTE still breeding in the wind-power plant area.

All transects were surveyed three times in the period 30 May 2007–1 July 2007, following procedures in Brown & Shepherd (1993). Transects were walked by an observer in good light conditions with no precipitation, and winds below Force 5 on the Beaufort scale. All birds observed on land or water within 100 m of the transect were identified and noted. The point on the transect perpendicular to the bird was noted using GPS, and the distance to the bird determined using a laser range finder. Birds flying over the transect were not recorded, except for skylarks in song flight. Males of this species make prolonged flights in which they hang in the air over their territory singing. Where possible locations of this species were recorded by waiting until the bird ceased flight and recording the point of landing; otherwise position was estimated as precisely as possible to the ground location the bird was over when first seen.

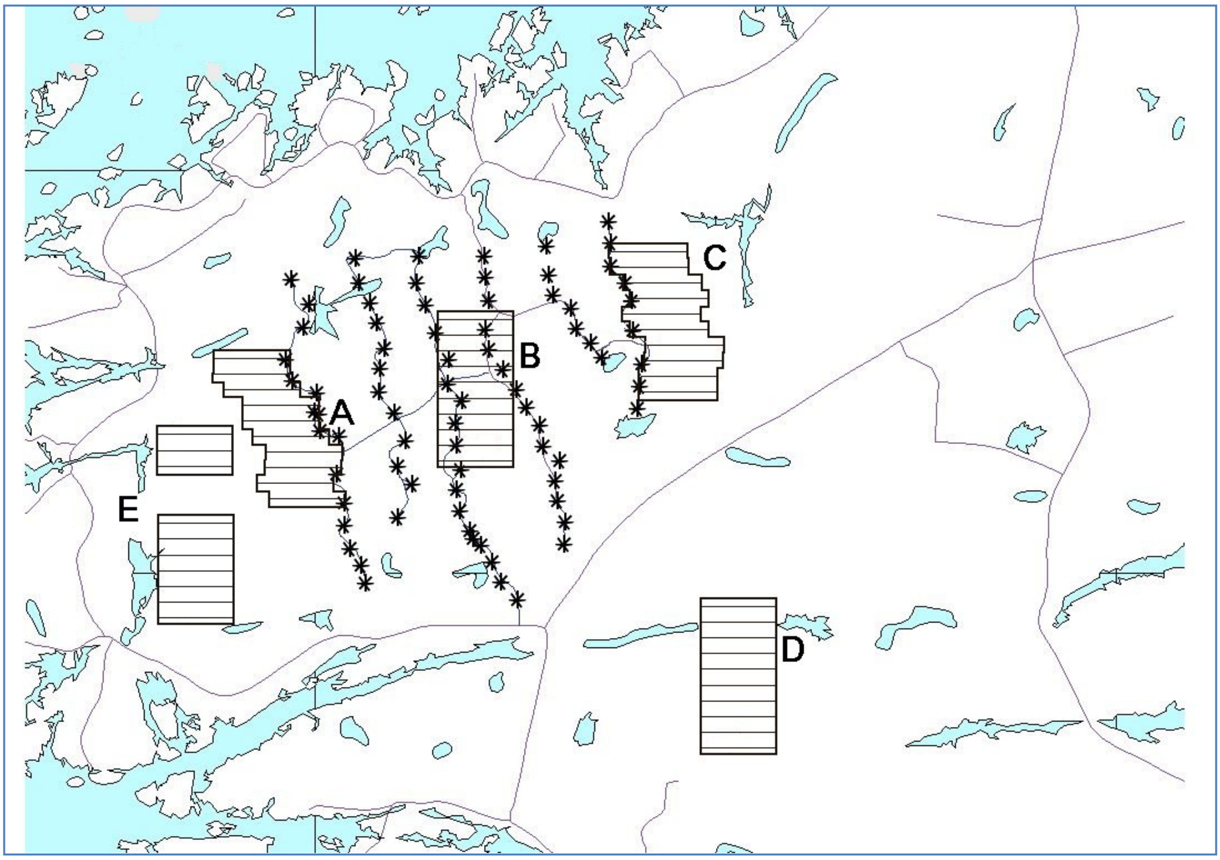


Figure 13. *Transect areas, showing 1 km long transect lines 200 m apart.*

Bootstrapping procedures were used to adjust for reduction in detectability of birds with distance from the transect line, assuming that birds were equally abundant at all distances 0-100 m from the line, and to increase effective sample size for statistical purposes (Manly 1997). The distance of each location to the nearest wind turbine location was calculated using GIS tools and programming developed for the purpose by Sigbjørn Stokke at NINA. A comparative set of random locations, with distances to the nearest turbine, was generated for each species and transect.

Real and random locations, in comparison to distances from the nearest turbine, were compared for each species in each of the transect blocks within and at the edge of the turbine array, using nonparametric techniques as the data was in most cases not normally distributed and/or not homogenous in variance.

The species of interest were breeding at the time of the study and dispersed as pairs, sometimes with recently fledged young birds, within the transect areas. Data was therefore analysed in terms of densities of bird 'clusters', i.e. one or more birds of the same species found in a group, as providing the most accurate guide to variation between transect areas in breeding densities. Densities of 'clusters' of birds of each species in each transect block, including control areas, were adjusted for detectability and calculated using the DISTANCE programme (Buckland et al. 1993, 2001).

4.2.2 Results

A total of 29 species of birds were recorded on the ground/water in the transect area (**Table 2**). Most were uncommon or rare (and one, the red-throated pipit, is a vagrant well outside its usual geographical range), so that it was not possible to determine whether they showed any behavioural responses to turbine presence or whether densities differed between transect blocks.

Table 2. *Bird species recorded. * indicates a species recorded only within the reference areas and not within the wind power installation or in transect areas at the edge of the installation.*

Latin name	**English name**	**Norwegian name**	**Total recorded**
Carduelis flavirostris	Twite	Bergirisk	8
Gallinago gallinago	Common snipe	Enkeltbekkasin	27
Cuculus canorus	Cuckoo	Gjøk	1
Anser anser	Greylag goose	Grågås	5
Ardea cinera	Grey heron	Gråhegre	6
Carduelis flammea	Mealy redpoll	Gråsisik	3
Turdus pilaris*	Fieldfare	Gråtrost	1
Haliaeetus albicilla	White-tailed eagle	Havørn	1
Pluvialis apricaria	Golden plover	Heilo	80
Anthus pratensis	Meadow pipit	Heipiplerke	229
Anas crecca	Teal	Krikkand	35
Anthus cervinus	Red-throated pipit	Lappiplerke	1
Motacilla alba	White wagtail	Linerle	12
Lagopus lagopus*	Willow ptarmigan	Lirype	1
Phylloscopus trochilus*	Willow warbler	Løvsanger	4
Caldris alpina	Dunlin	Myrsnipe	45
Corvus corax	Raven	Ravn	1
Tringa totanus	Redshank	Rødstilk	13
Alauda arvensis	Skylark	Sanglerke	29
Mergus serrator	Red-breasted merganser	Siland	12
Emberiza schoeniclus	Reed bunting	Sivspurv	5
Gavia stellata*	Red-throated diver	Smålom	13
Numenius phaeopus	Whimbrel	Småspove	2
Oenanthe oenanthe	Wheatear	Steinskvett	160
Anas platyrhynchos	Mallard	Stokkand	3
Actitis hypoleucos	Common sandpiper	Strandsnipe	17
Sturnus vulgaris	Starling	Stær	11
Turdus merula	Blackbird	Svarttrost	2
Stercorarius parasiticus	Arctic skua	Tyvjo	18

Detectability of birds declined with distance from the transect line, as shown in **Figure 14** (see methods for analyses of data adjusted for this effect).

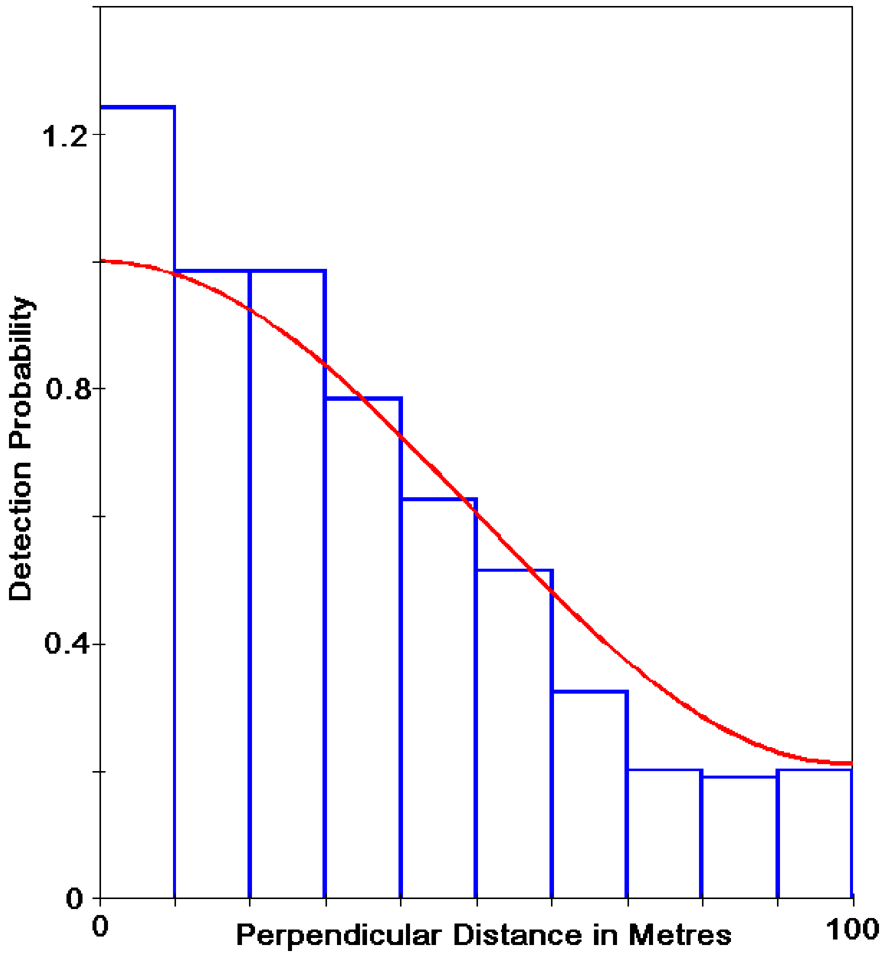


Figure 14. *Probability of detection of birds in relation to distance from the transect line, Smøla. Data is for all birds and all transect areas combined.*

It was possible to analyse bird position with regard to turbine proximity for five species: two waders, dunlin and golden plover; and three passerines, wheatear; meadow pipit; and skylark. Not all of these species were found in all transect areas. Although teal were relatively common, 15 of the individuals recorded were three groups of a female with chicks. Snipe were distributed so evenly over the area that in no transects area were numbers large enough for analysis. Willow grouse were certainly greatly under-recorded. The species has cryptic plumage and responds to predators such as humans by freezing, except when approached to within a few metres.

Figures 15a-c give boxplots of distances from the nearest turbine for the species with populations sufficiently large for statistical analysis (bootstrapped data) in each transect area A-C, compared with randomly generated locations.

A potential confounding factor for area C is that the terrain changed with distance east from the turbine array edge, from blanket bog nearer the turbines to broken hummocky moorland with rocky outcrops further east. The other two areas were of a homogenous habitat mosaic, broken hummocky moorland interspersed with rocky outcrops and marshy areas, including small tarns.

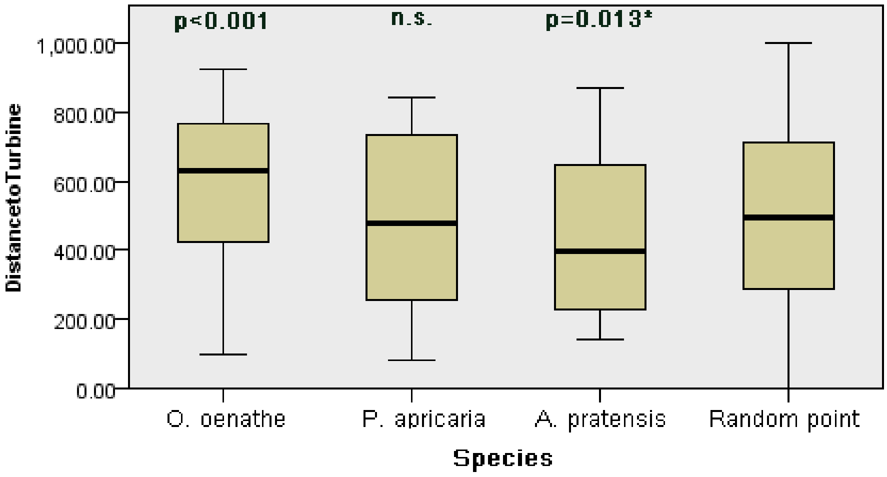
Both within the turbine array and at the western edge the meadow pipit was found slightly, but significantly, *closer* to turbines than would be expected on random distribution. The reasons for this effect are unclear (see discussion), but as it occurs in both areas where there are no systematic changes in terrain type with distance to turbine this would appear to be a genuine effect.

The only other species found closer than expected to turbines was the dunlin in Area C. However, this species prefers blanket bog habitat, which within Area C was found closer to the turbine array edge, and this, rather than a preference for turbine proximity, is the probable cause of the observed effect. In area B, where habitat was relatively homogenous, the dunlin was found further away from turbines than would be expected if distributed randomly; though this may be due to a preference for small marshy microhabitats within that area, which would on average be further from turbines as the bases of turbines are normally placed on a rocky substrate (see discussion).

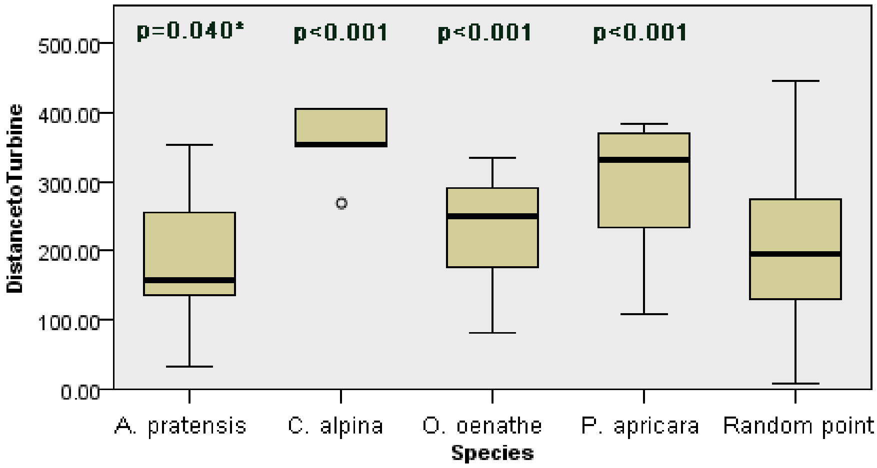
The wheatear was always found further than would be expected from turbines, in all three transect areas, although the species prefers the exposed, partly rocky terrain favoured as the site of turbine bases. The golden plover was found further than expected from turbines in areas B and C, with no effect observed in Area A. The skylark, which was only found in Area C, showed no significant effect of proximity to turbines in that area.

Figure 16 a-e summarises the calculated densities of bird species recorded in the various transect areas. Overall densities of birds varied widely between species, as would be expected, and most species occurred at very low densities. Mean densities of the four most common species, in relation to transect area, are shown in **Figure 17 a-d**. Error margins for the estimates are high, as a result of the relatively low densities of even these species.

a) Area A (west edge of turbine array)



b) Area B (within turbine array)



c) Area C (east edge of turbine array)

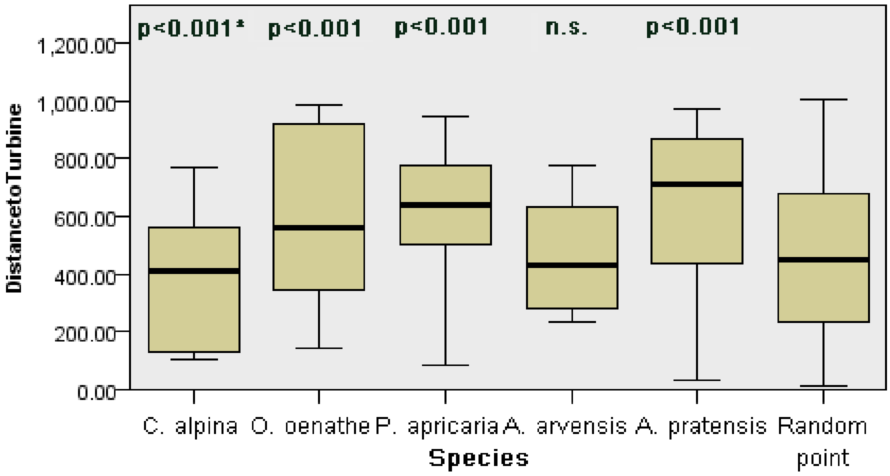


Figure 15 a-c. *Distances of locations of birds and randomised points to the nearest turbine in three 2 km^2 transect areas. Data is bootstrapped (see methods). Results of Mann-Whitney comparisons of distance to turbine for each species compared with random locations are indicated. * indicates the species was found significantly closer to turbines than expected; other significant results indicate the species was found further away than would be expected if distributed randomly with respect to turbines.*

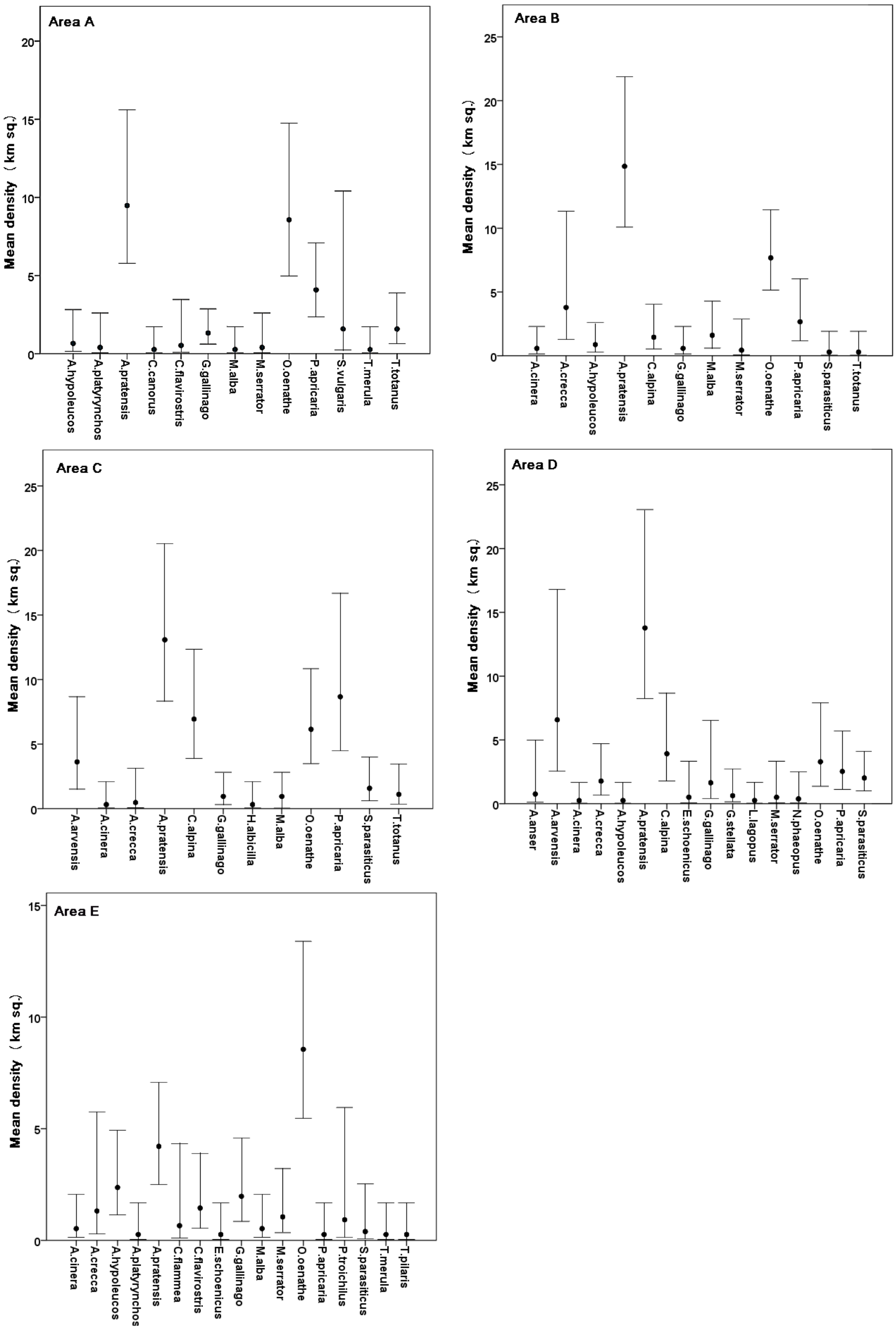


Figure 16 a-e. *Densities of birds in the different transect areas (calculated using the DISTANCE programme)*.

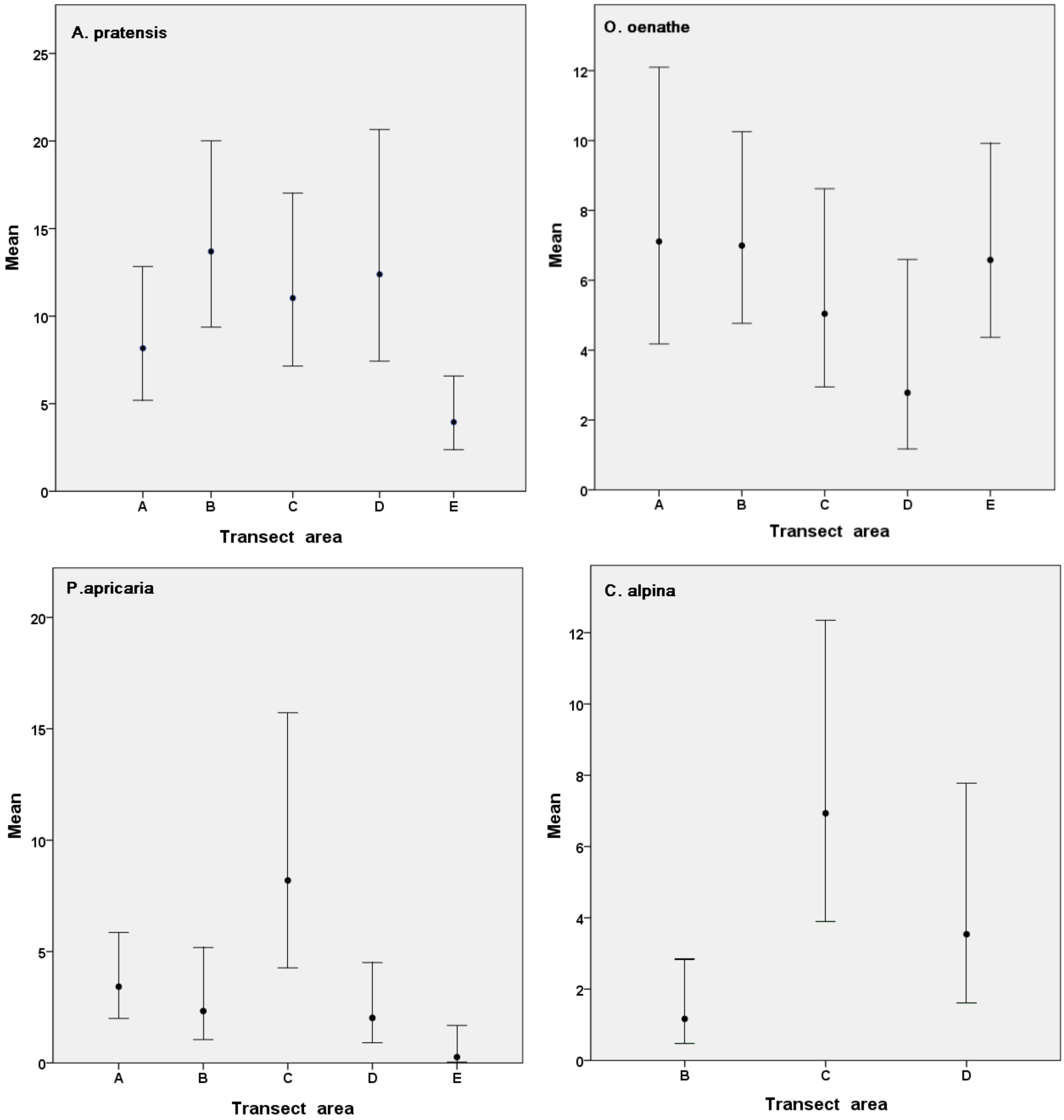


Figure 17 a-e. *Mean densities of the four commonest species in the wind power-plant area, by transect area, as calculated by the DISTANCE programme.*

4.2.3 Discussion - Smøla

The wind SWPP area contains relatively low density populations of wader and passerine species which are common in Norway and on a world scale. These low densities make it relatively difficult to discern variation between transect areas in distribution and densities. Nevertheless, our data demonstrate a significant relationship between turbine location and both the mean distance of certain bird species to turbines, and to a lesser extent of overall species densities.

Wheatears were found highly significantly further away from turbines than would be expected on a random distribution, in all three transect fields. Meadow pipits were, conversely, found *closer* than expected to turbines in areas A and B; but further away than expected in area C. Golden plover were found significantly further than expected from turbines in areas B and C; and dunlin further than expected in area B; but closer than expected in area C.

As noted, there are two potential confounding factors in the Smøla data set. The first is that turbines, especially in area B and on the edge of Area A, tend to be sited on rocky outcrops rather than intervening boggy areas. The second is that the western edge of Area C (the edge adjacent to turbines) is blanket bog, but the terrain becomes increasingly flecked with rocky outcrops and hummocks eastwards.

The meadow pipit, wheatear and golden plover are all species which prefer rockier areas with outcrops, especially as places to observe from when alarmed, which is likely to be the case when human observers are nearby. They will also be more easily detected in such places. One might expect, therefore, that they would be found more commonly closer to turbines in areas A and B, since turbines are most often placed in such areas; and further away in area C, as the habitat is more suitable at distances further from the turbine. This pattern is observed for the meadow pipit, but the opposite pattern is observed for the wheatear and golden plover. This suggests that the avoidance effect is real for those species, and that they are disproportionately avoiding the vicinity of turbines.

The dunlin data is consistent with habitat as the main factor affecting the results, as the boggy habitat the species prefers is found disproportionately in the western part of the transect area C, closer to the turbines. In area B, where boggy areas and rocky outcroppings are mingled, the species prefers the boggy habitat, which is not preferred for siting of turbine bases. It is not therefore possible to distinguish any effect of avoidance of turbines, which may be masked by the preference for boggy habitat.

4.3 The 2008 pre-construction baseline study at Andmyran, Andøya

4.3.1 Methods

Fifteen 1 km transects were defined in the planned wind power-plant area, in three blocks of five transects covering an area of 1 km each, following the methods used for Smøla, above. Each transect was surveyed three times in the period 2 July 2008-17 July 2008 (the breeding season is later on Andøya, which is approximately 650 km north of Smøla).

The proposed area of Andmyran wind power-plant is shown in **Figure 18**. The area is mainly flat mire (**Figure 19**), with patches of birch scrub on drier locations, lying between the eastern coast of Andøya and the mountain spine of the island. There are significant populations of breeding waders (Bjerke et al. 2004) and several passerine species present.

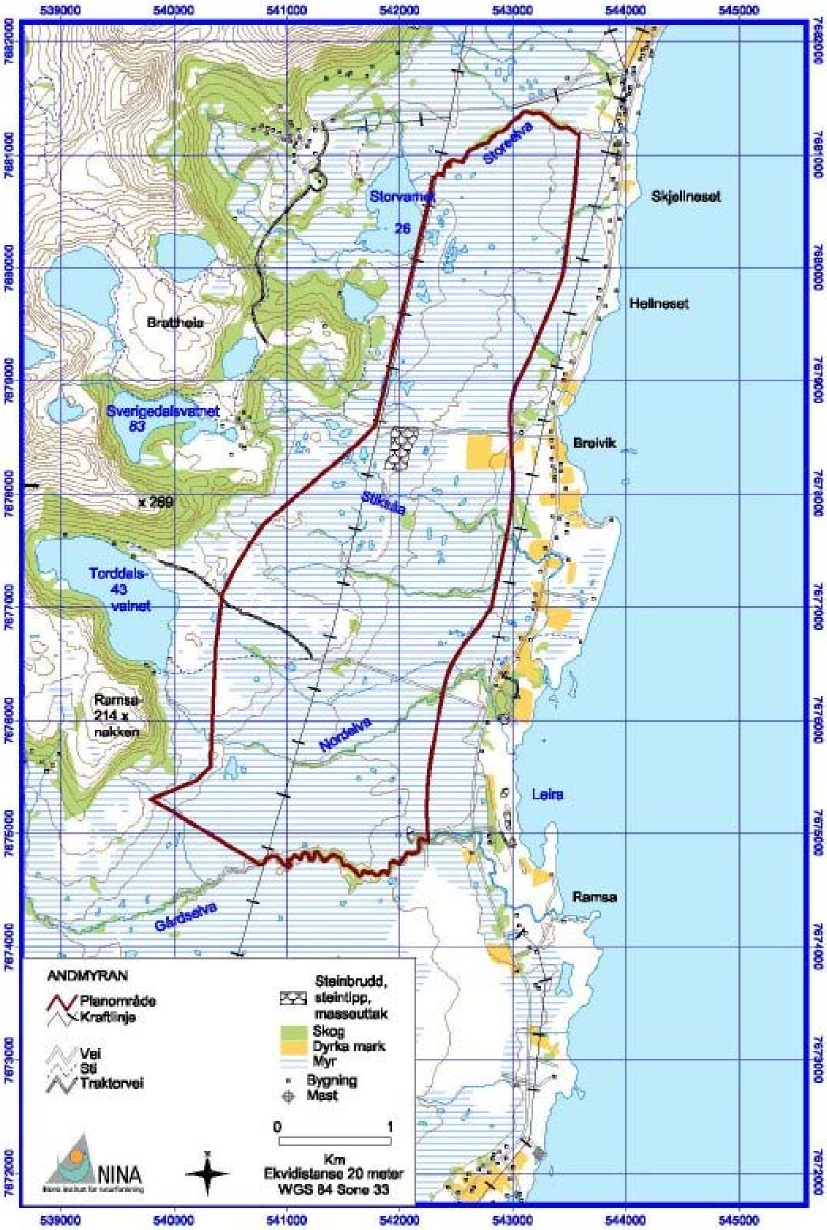


Figure 18. *Proposed perimeter of Andmyran wind-power plant (map from Bjerke et al. 2004).*

Figure 19. *Site of proposed Andmyran wind-power plant and of baseline pre-construction wader and small passerine censuses in 2008. Looking north from the SW perimeter of the plan area, July 2008.* Photo: D.J. Halley.

4.3.2 Results and interim conclusion - Andmyran

Data analysis will take place after comparative data is obtained in the post-construction phase. This site also has significant raptor populations, particularly WTE which pass regularly through the area between the coast and nesting sites in the hills to the west. The site is largely peat bog, with associated botanical and hydrological concerns with regard to wind power development. It would be highly suitable for comprehensive before-and-after and control-impact (BACI) assessments in many respects, not simply for small birds and waders. Few such studies have yet been performed (Drewitt & Langston 2006) and work using Andmyran as a model would be likely to yield high quality information of potentially very wide applicability.

4.4 The 2009 EIA-studies on Hitra

4.4.1 Methods

Standard line-transect methods (Buckland et al. 1993, 2001) were used in the plan area. 12 transects were defined in an east-west orientation, each 1 km in length except for LVN1 (921 m) and LVN2 (919 m) covering all the larger areas in the development plan as then defined (**Figure 20**). The exact length of each transect was taken into account in all subsequent analysis.

Data was collected from each transect on three occasions in the period 22nd May-9th July 2009, this being the breeding season for most of the bird species expected in the area and the time of year in which birds are normally easiest to. Individuals were registered in a band from 0-100 m north and south of the transect line. The distance to the observer was measured using laser binocular rangefinders, and the DISTANCE programme used to estimate detection probability at various distances (Buckland et al. 2001).

Densities of birds were calculated from this data using DISTANCE, though in this case (see below) densities, especially on the mountain plateau, were often too low for estimates to be calculable. All ponds and lakes on the periphery of the plan area were checked for waterfowl on every visit. Outside structured observations, all casual records of less common birds, and the location of any nests found, were noted by all members of the project team.

4.4.2 Results

The number of birds of the various species observed is presented in **Table 3**. The results indicate a clear difference in species diversity and densities between the mountain plateau on Eldsfjell (all transects except RH1-4) and in the Korsvatnet – Ramnåsheia area (RH1-4). The density of birds on the Eldsfjell plateau was low and consisted mainly of three species, meadow pipit, wheatear, and golden plover. Willow grouse and redshank were also observed. The only observations of other species in the Eldsfjell area were in or near small cliffs with scrub at the edge of the area, two twite and two kestrels (one observed outside structured observations); both possibly breeding pairs.

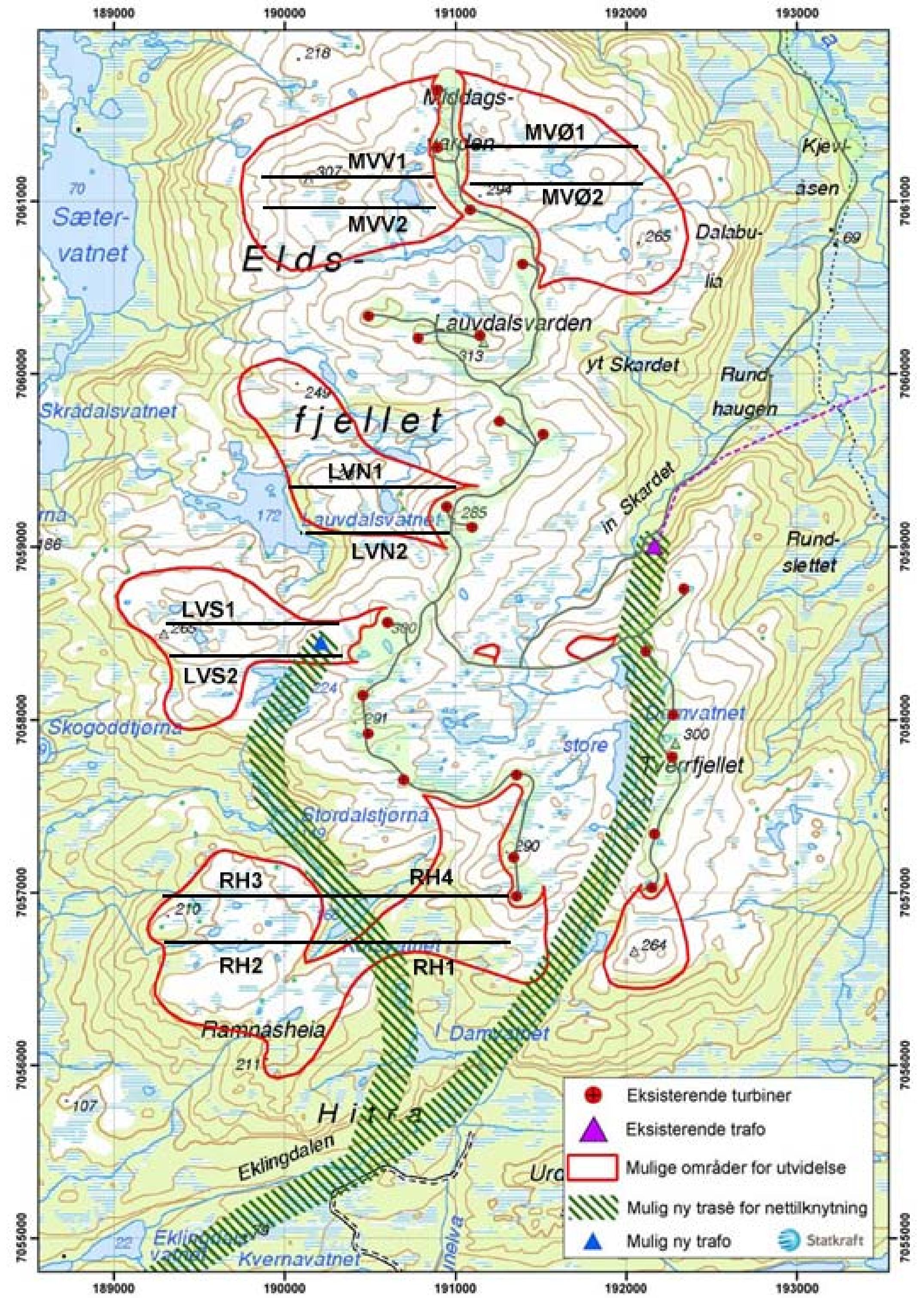


Figure 20. *Location of transect lines for small birds and waders in the plan area for the Hitra II wind-power plant. Transects were 100 m in length, with the exceptions of LVN1 (921 m) and LVN2 (919 m).*

Table 3. *Total number of birds of each species observed during transects counts of the plan area for the Hitra II wind-power plant.*

Latin name	**English name**	**Norwegian name**	**Total re corded**
Carduelis flavirostris	Twite	Bergirisk	2
Fringilla coelebs	Chaffinch	Bokfink	20
Poecile montanus	Willow tit	Granmeis	16
Phylloscopus collybita	Chiffchaff	Gransanger	7
Carduelis flammea	Mealy redpoll	Gråsisik	2
Pluvialis apricaria	Golden plover	Heilo	8
Anthus pratensis	Meadow pipit	Heipiplerke	46
Prunella modularis	Dunnock	Jernspurv	2
Parus major	Great tit	Kjøttmeis	9
Bucephala clangula	Goldeneye	Kvinand	3
Lagopus lagopus*	Willow ptarmigan	Lirype	1
Phylloscopus trochilus*	Willow warbler	Løvsanger	5
Turdus philomelus	Song thrush	Måltrost	4
Corvus corax	Raven	Ravn	1
Tringa totanus	Redshank	Rødstilk	3
Scolopax rusticola	Woodcock	Rugde	1
Phoenicurus phoenicurus	Redstart	Rødstjert	3
Erithacus rubecula	Robin	Rødstrupe	1
Turdus iliacus	Redwing	Rødvingtrost	2
Oenanthe oenanthe	Wheatear	Steinskvett	25
Anas platyrhynchos	Mallard	Stokkand	6
Actitis hypoleucos	Common sandpiper	Strandsnipe	2
Periparus ater	Coal tit	Svartmeis	2
Turdus merula	Blackbird	Svarttrost	8

Casual observations of grey-headed woodpecker (1) and ring ouzel (1) were noted outwith the transects; the former close to the southernmost existing turbine, and the latter (an adult male) in the eastern part of Middagsvarden. A meadow pipit nest with four eggs was found about 10 m from the base of the same turbine. The mountain plateau of Eldsfjellet appears relatively impoverished both in species and in numbers of small birds and waders, which is not surprising considering the infertile underlying rock (granite), the highly exposed location, and the sparse soil coverage outwith patches of mire.

The Korsvatnet-Ramnåsheia area in the southwest lies lower than Eldsfjellet; this part of the plan area is dominated by relatively fertile mixed pine/birch woodland in natural succession, with considerably better developed soils than on the mountain plateau. Trees on the top of Ramnåsheia are more sparse and patchy, and the trees more bushy in form, but nevertheless support a number of typical woodland species along with species associated with more open terrain, especially where there are patches of open mire. This area has a considerably higher density of birds, as well as a greater diversity of species. Chiffchaff, willow warbler, chaffinch, song thrush, redwing, blackbird, willow tit, great tit, siskin, robin, and dunnock were all common. Coal tit, redpoll, redstart, raven, willow grouse, woodcock, and common sandpiper were also observed. Woodpeckers are difficult to register through direct observations, but marks on trees show that woodpecker species are also common. Eight grey-headed woodpeckers were observed outwith transect observations in woodland area on the southwest and western flanks of the Eldsfjellet massif spring-summer of 2009; further data (M. Pearson pers. comm.) shows a dense (for the species) concentration of grey-headed woodpeckers, in this area, which includes Ramnåsheia and the area adjacent to the top 265 m southwest of Lauvdalsvatnet (**Figure 21**).

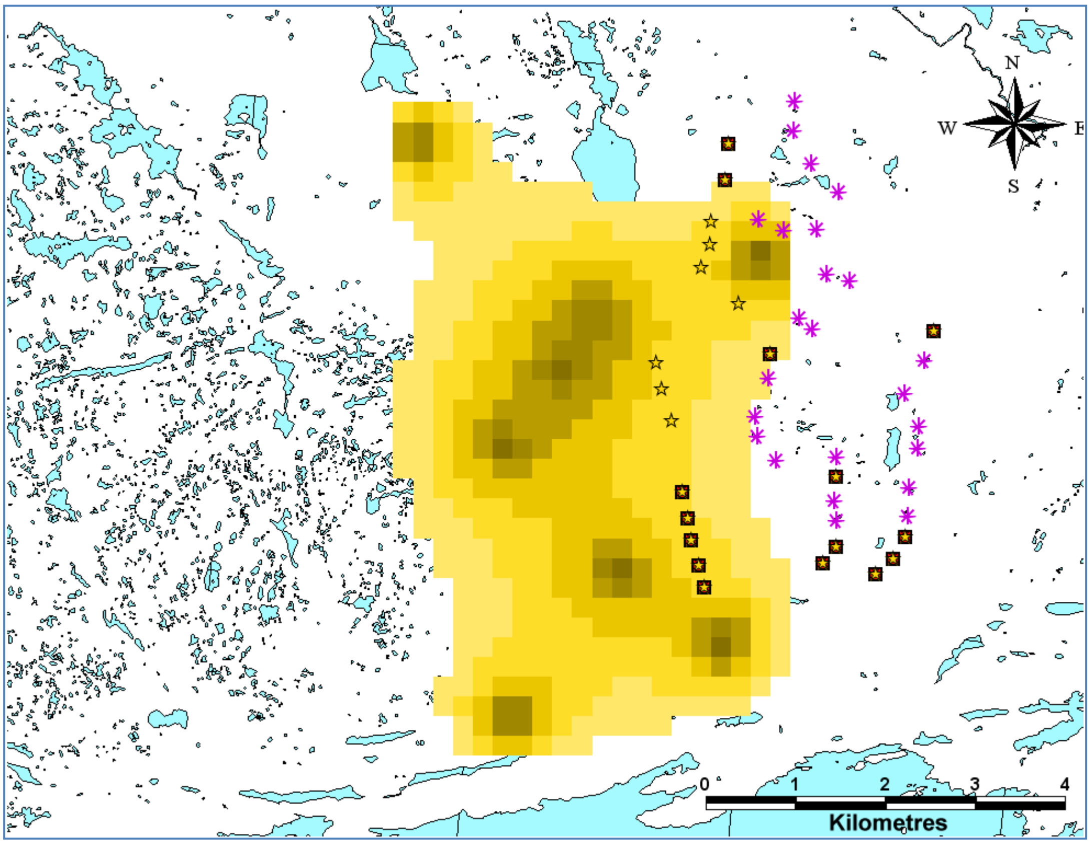


Figure 21. *Relative density of grey-headed woodpecke in the Ramnåsheia area. Small stars indicate existing wind turbines, proposed turbines under Alternative A as squares and under alternative B as yellow stars. Darker colours indicate increasing densities (white = area not assessed). Data: M. Pearson (pers. comm.).*

Waterfowl are not common on lakes or ponds either in the plan area, or in the valleys between ridges of the south-western Eldsfjellet massif. A female goldeneye with five ducklings was seen on Lauvdalsvatnet, and a mallard female with five ducklings on a pond on the top of Ramnåsheia. Two female goldeneyes were seen on Korsvatnet. Diver species did not apparently breed within or adjacent to the plan area in 2009, although a black-throated diver was seen on Skogoddvatnet ca. 1 km west of the plan area in spring, and breeding on lakes or ponds on the edge of the plan area cannot be excluded in the future. Data from Smøla (Halley & Hopshaug 2007) indicate that breeding in the wind-power plant area after construction is unlikely. The whooper swan breeds on Skogoddvatnet and one pair was seen on Tømmeråstjønna, ca. 2 km northwest of the plan area (M. Pearson pers. comm.).

4.4.2.1 Analysis of densities using DISTANCE

The DISTANCE-programme calculates the probability that a bird will be detected at a given distance from a transect (Buckland et al. 1993, 2001). From this a model is constructed to estimate the actual densities of birds in the area. **Figure 22** shows the calculated chance of detection, based on the data collected in this study.

From the data, an overall density of 36.47 birds/km^2 (+/-8.56 SE) is calculated. This is a relatively low number, but conceals a large difference in densities between the plan areas on Eldsfjell and Ramnåsheia (**Table 4**).

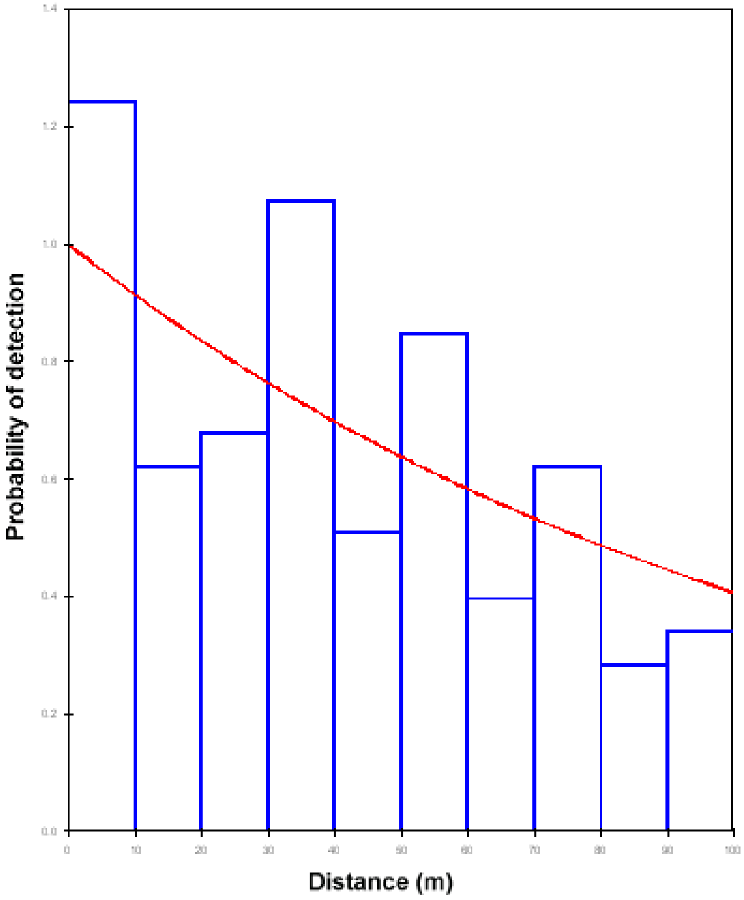


Figure 22. *Detection probabilities for all birds and all transects combined to a distance of 100 m from the transect line*

Table 4 *Density of small birds and waders in various parts of the plan area (the 95% confidence interval of the LVN transects is extremely high due to the very low number of birds (8) recorded in the area.*

Transect	Birds/km^2	SE	% coefficient c variation	95% confidence interval (lower)	95% confidence interval (upper)
MVØ1-2	28.3	6.7	23.7	16.9	47.4
MVV1-2	40.0	3.4	8.5	33.3	47.9
LVN1-2	16.3	9.5	58.6	0.0	4319.9
LVS1-2	25.0	5.0	20.0	15.8	39.9
RH1-4	163.3	14.6	8.9	136.5	195.3

The mountain plateau areas of Eldsfjellet (all transects except RH1-4) have a bird density of between 16.3 and 40 birds/km^2 while the Ramnåsheia area (RH1-4) has a density of 163.33 birds/km^2, i.e. between 4 and 10 times higher. The diversity of species was also higher, with 21 species registered in the four Ramnåsheia transects compared to 10 in the eight transects on Eldsfjellet (combined).

The density of individual species in the various areas on Eldsfjellet was without exception too low to calculate density estimates. Density estimates for the commonest species in the Ramnåsheia area are shown in **Table 5**.

Table 5. *Densities of the most common small bird species in the Ramnåsheia area.*

Species	Birds/km^2	SE	% coefficient c variation	95% confidenc interval (lower)	95% confidence ir terval (higher)
Chaffinch	32.6	9,8	30.0	17.7	59.8
Willow tit	40.1	12.5	31.3	20.9	77.0
Meadow pipit	25.0	9.2	37.0	10.8	57.9
Blackbird	12.5	2.4	19.2	8.5	18.35

4.4.3 Discussion - Hitra

Small bird and wader populations within the Eldsfjell plateau part of the plan area consist of low density and low diversity populations of common small passerines and waders. The danger of negative consequences for these species apart from at a very local scale is consequently low. Breeding of meadow pipits was confirmed within 15 m of an existing turbine. Two of the species, the wheatear and the twite, registered on Eldsfjell, were red listed in the former Norwegian Red List (Kålås et al. 2006), but they have now been removed (Kålås et al. 2010). The twite still is a species of special responsibility ("ansvarsart") for Norway. The twite was uncommon in the plan area (1 observation, 2 individuals), probably because of a lack of suitable habitat locally.

Both species diversity and densities were considerably higher in the Plan area around Ramnåsheia. This is because the area is at a lower elevation and is to a large extent wooded; even the top of Ramnåsheia is to a significant degree patchily covered with bushy or dwarfed trees (due to the exposed location). This area must therefore be considered separately from Eldsfjellet. Most species found here are common in Norway, with the exception of the grey-headed woodpecker, which has a relatively high density population in some of the woodland within and adjacent to the plan area. However, this species has now been removed from the Norwegian Red List. The risk of collisions with turbines and power lines, and/or population declines due to habitat loss/fragmentation and disturbance related to turbine maintenance and operation, is probably higher in this area given the higher absolute density of birds of various species.

Results from transects on Eldsfjellet can with appropriate caution be extrapolated to other areas on the mountain plateau above the tree line, and data from the Ramnåsheia area can be considered broadly representative of similar areas on the flanks of Eldsfjellet. Taken together, the data suggests there is little risk of significant negative consequences to the species studied if a Hitra II development is built on Eldsfjellet. In lower lying areas on the edge of the massif, such as Ramnåsheia and similar areas to the north, risks associated with development are somewhat higher, given the denser and more diverse bird fauna. This includes possible effects on the grey-headed woodpecker population; other small bird and wader species known to occur in the area are relatively common. The low densities of birds on Eldsfjellet in particular mean that the potential of this area for before-and-after studies of bird populations is very limited, as changes in densities would be difficult to detect.

Populations of waders and small birds are not dense on Smøla, or on Hitra on the open ground of the Eldsfjellet massif. This has meant that analysis of effects has not been practical for the majority of species which occur there. On Smøla, however, some important effects were observed for the commoner species, which do not appear to be potentially explainable by systematic biases in turbine positioning with respect to habitat (see discussion above). Specifically, wheatears were found highly significantly further away from turbines than would be expected on a random distribution, in all three transect fields within and adjacent to the turbine array. For waders, golden plover were found highly significantly further than expected from turbines in two of three of these transect areas, with no significant effect noted in the other.

It is unclear what the factor or factors causing this effect are. Possibilities include: 1) increased direct mortality of birds breeding close to turbines through collisions with rotor blades. This is particularly hard to estimate for small birds, especially if searches are performed without a specially trained dog. Carcasses of this size are hard to detect and may be easily removed by scavengers such as ravens (Smallwood 2007, Drewitt & Langston 2008). 2) The ancillary infrastructure of roads and car parks, and/or the increased disturbance by cars, humans, dogs etc. along these roads (Drewitt & Langston 2006).

Our results are broadly in line with results elsewhere, which also demonstrate a tendency to avoidance of the vicinity of turbines in similar habitats by small birds (Leddy et al. 1999), and specifically of wheatear and golden plover*,* among other species (Pearce-Higgins et al. 2009). Pearce-Higgins et al. (2009), based on data from UK wind power installations, predict a substantial decline, of 44.4% (95% CI 4.9-65.2%) in wheatear, and 38.9% (95% CI 4.3-59.0%) in golden plover, breeding densities, as a result of wind power developments in similar landscapes to all of the wind power installations studied here. Birds in other, more anthropogenic landscapes, such as intensive farmland, may however be more robust to wind power developments (Deveraux et al. 2008).

Pearce-Higgins & Yalden (2005) suggest that for golden plover in particular, the outcomes of censuses of this type nevertheless need to be treated with some caution, because of the species' relatively long breeding season, with the beginning of egg laying occurring over several weeks and incubating adults being hard to detect. This can lead to underestimates of densities, especially where densities are high. However, systematic differences in detectability between transect areas on Smøla seem unlikely, as there are no reasons to indicate that breeding timing varies between transect areas; and there are no grounds to conclude that this would have an effect on how far birds which were observed would be from turbines.

There is no evidence from our data that turbine placement affects the distribution of meadow pipits negatively, and a nest with eggs was recorded within 10 m of a turbine on Hitra; however any effect may be masked by the influence of habitat availability, which on Smøla is distributed in a very fine scale mosaic. Pearce-Higgins et al. (2009) note a significant avoidance of turbines from sites in the UK, with a predicted decline in abundance as a result of turbine placement of 14.7% (95% CI 2.7-25.1%).

For the wheatear, now removed from the Norwegian red list, our evidence indicates a negative effect of wind power development, and data from the UK suggest the effect can be substantial. However, the species remains one of the commonest birds in these types of habitat in Norway.

The wind power installations on Smøla and Hitra have been operating for a relatively short time, and the data presented here represent a snapshot from one year. Little is known about the long-term effects of installations on bird densities and breeding; however, existing data indicates that longer-term impacts do occur, can be significant, and may be overlooked by relying on surveys made a short time after construction (see Stewart et al. 2007 for review).

Our results are therefore consistent with the emerging pattern of data elsewhere, indicating that wind power installations can negatively affect densities of breeding birds (7 of 12 species in

Pearce-Higgins et al.'s (2009) analysis, with the other 5 species showing equivocal results). For some species this effect is very highly significant. Whether this would result in any significant population-level effect would depend on the potential for mitigation, which is unclear pending a better understanding of the mechanisms involved; and how significant a proportion of the bird's total habitat is affected by wind power developments. In Norway, for the species common enough for statistical analysis in this study, this proportion is currently negligible on a regional and national scale and is likely to be so for the foreseeable future.

However, the behaviour of these species with regard to wind turbines is likely to be representative of similar but much rarer small birds and waders. There are, therefore, grounds to consider that the construction of a wind power installation on sites with high breeding concentrations of those species could have a significant adverse impact on their populations. The precautionary principle would thus indicate that sites with concentrations of breeding, rare small birds or waders should be avoided, unless there is positive evidence that there would not be adverse effects on the breeding population. Such sites are likely to be uncommon in the Norwegian landscape as a whole, with many suitable alternatives from an energy production standpoint available.

Appropriate planning guidelines, and power industry scoping practices, should therefore take this factor into account. Indicative mapping of vulnerable areas in Norway, as practised elsewhere in Europe (Bright et al. 2008), would greatly assist such scoping activities, and prevent most such conflicts arising. This would greatly reduce the associated environmental problems; planning delays or refusals; and significant financial costs which are typically associated with planned developments at conflict sites (Toke et al. 2008).

Pre-construction studies at Andmyran (above; Bjerke et al. 2004) suggest considerable potential at that site for well-structured BACI-studies of a number of factors, including effects on small birds and waders. As such studies are currently rare, and provide a better basis for conclusions which can be generalized to other sites than comparative studies, further work at the site would be advantageous both scientifically, and as an aid to improved planning of wind energy development.

4.4.4 Preliminary conclusions and remaining questions

- There is evidence that several species of small birds and waders avoid the vicinity of wind turbines on Smøla.
- All of these species are, however, common on a regional, national, and world scale and none of them are listed in the 2010 revision of the Norwegian Red List.
- However, if this behaviour is representative of rarer, small birds and waders it may be significant for their populations if wind-power plants are built on or close to concentrations of such species, either in the breeding season or at other times.
- The precautionary principle would suggest avoiding building wind-power installations in such areas, which will probably be rare in Norway with many alternative sites available.
- Study of effects on such rarer birds (e.g. ruff) may be useful, if practical to achieve.
- The proposed wind power development at Andmyran (approved but not yet constructed) would be very suitable for a BACI (before and after and control-impact – approach) study of effects on small birds and waders, and other species. Such studies are currently rare and offer better quality data than other approaches.

5 White-tailed eagle

5.1 Satellite telemetry

Subproject responsibility: Torgeir Nygård

Objectives: To use satellite telemetry to acquire information on white-tailed eagle movements and data for collision risk assessments.

5.1.1 Introduction

Approximately 55-60 WTE territories are found in the whole Smøla archipelago. Before construction there were 13 eagle pairs holding territories in the SWPP area and within 500 m of it, whereas in 2010 this was reduced to only four. Since 1996, baseline data on the WTE population size and reproduction have been collected.

In a post-construction study, 59 fledglings were satellite-tagged during 2003–2010, of which 54 provided more than 125 000 GPS positions in total. In addition to the geographical location, data on altitude and flight speed were provided by the transmitters (Microwave Telemetry, Inc., Columbia, MD, USA). Juveniles of both sexes stayed within the Smøla archipelago during their first winter. Most individuals moved away from the area during spring in their second year (April–May). Females dispersed further than males, often more than 800 km during summer, generally to the north. There was a return movement to the natal area during the second autumn. The same pattern was repeated in the third and fourth years for females, while the males showed more philopatry (Bevanger et al. 2009).

From August 2005 to December 2010, four of the satellite-tagged birds were killed by collisions with turbines, of 39 WTE in total, involving 21 adults, 11 immatures and seven juveniles. Additionally, one of the satellite-tagged juveniles was killed in an electrocution accident. April and May are the months with the highest collision frequencies, and 28 (72%) of the known fatalities have been found between March and early June.

Risk assessments were performed based on GPS positions of the birds during the different months of the year and the age of the birds. The transmitters were programmed to transmit their positions at different intervals. Long time intervals (up to 24 h) were used during winter, 3–6 h during spring and autumn, and 1–3 h during summer. An analysis of moves showed that the birds changed positions on average 15 times per day, using a 100 m difference between positions as an indicator of movement. Every change in position was considered to involve a collision risk when the birds were at Smøla and its archipelago. Moves when they were elsewhere were not considered. Monthly 95 % and 50 % utilization distributions (UDs) (Worton 1989) were produced using the positions from the Smøla archipelago only, with all birds in each month and age-class pooled. The expected number of moves by each bird was estimated by weighing the number of obtained positions by a factor equal to 15 divided by the pre-programmed number of positions taken for each transmitter and month. The total number of expected moves (M_e) was then obtained by summing over all birds for each calendar year and month. Kernel UD (95 % and 50 %) areas by calendar year and month (A_{k95} and A_{k50}) were produced via ArcView 3.3, by using cross-validation and the default smoothing factors. The total rotor-swept area (RSA) (A_{t95} and A_{t50}) of turbines that overlapped each kernel area was found by multiplying the number of turbines by the RSA (r^2, where r is the radius of the rotor-blades). The probability of each position being within an RSA was then calculated as A_{t95}/A_{k95} and A_{t50}/A_{k50} for each calendar year and month. The expected number of positions within an RSA was then calculated as M_e*0.95 A_t/A_k and M_e*0.5 A_t/A_k for the 95 % and 50 % kernel areas, respectively, for each calendar year and month.

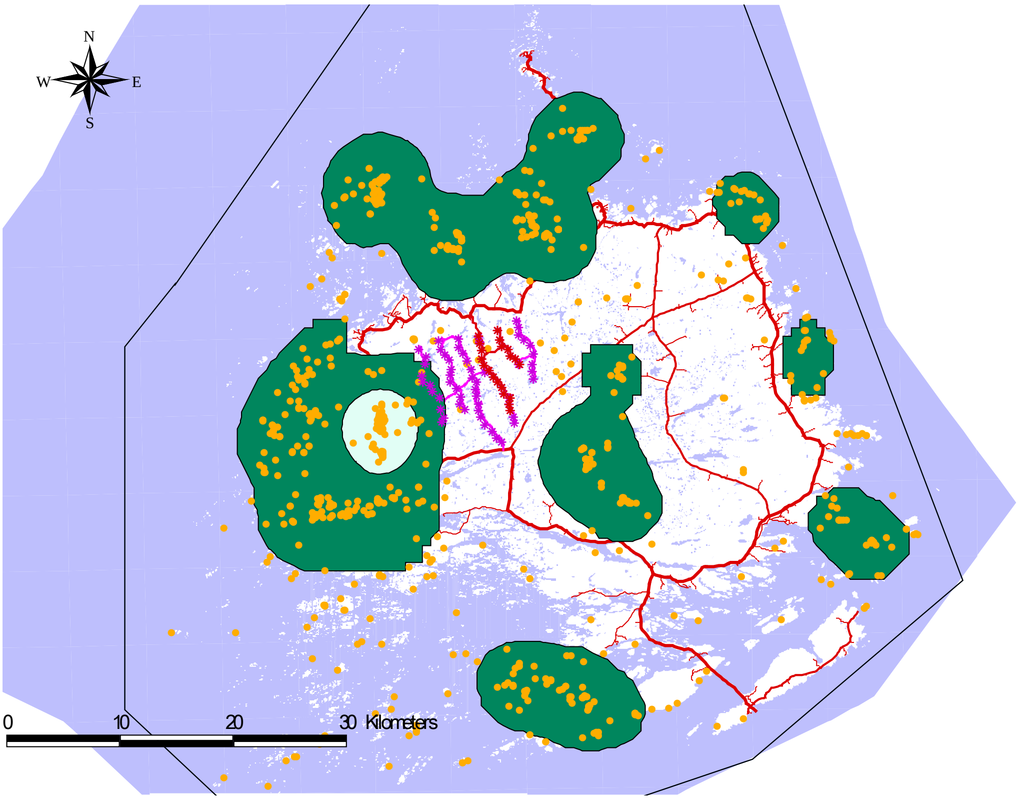


Figure 23. *Position of satellite-tagged juveniles (orange dots) during October-December in their first year of life at Smøla, showing their 50% (light green) and 95% (dark green) kernel utilisation distributions.*

Based on information from 34 birds for which the altitude was known (birds in their nests), a standard deviation of altitude of 7.8 m was found. This was considered sufficient to produce an estimate of the fraction of the flights within the rotor height. Using only the data from positions when the birds were assumed to be flying (speed >0), we found that on average 24% of the flights in the SWPP were within the rotor height. Calculations with and without this figure as an adjustment factor was used. **Figure 24** shows the expected number of positions within an RSA per calendar year and month based on 95% and 50% UDs, and the number of actual kills of tagged birds was recorded.

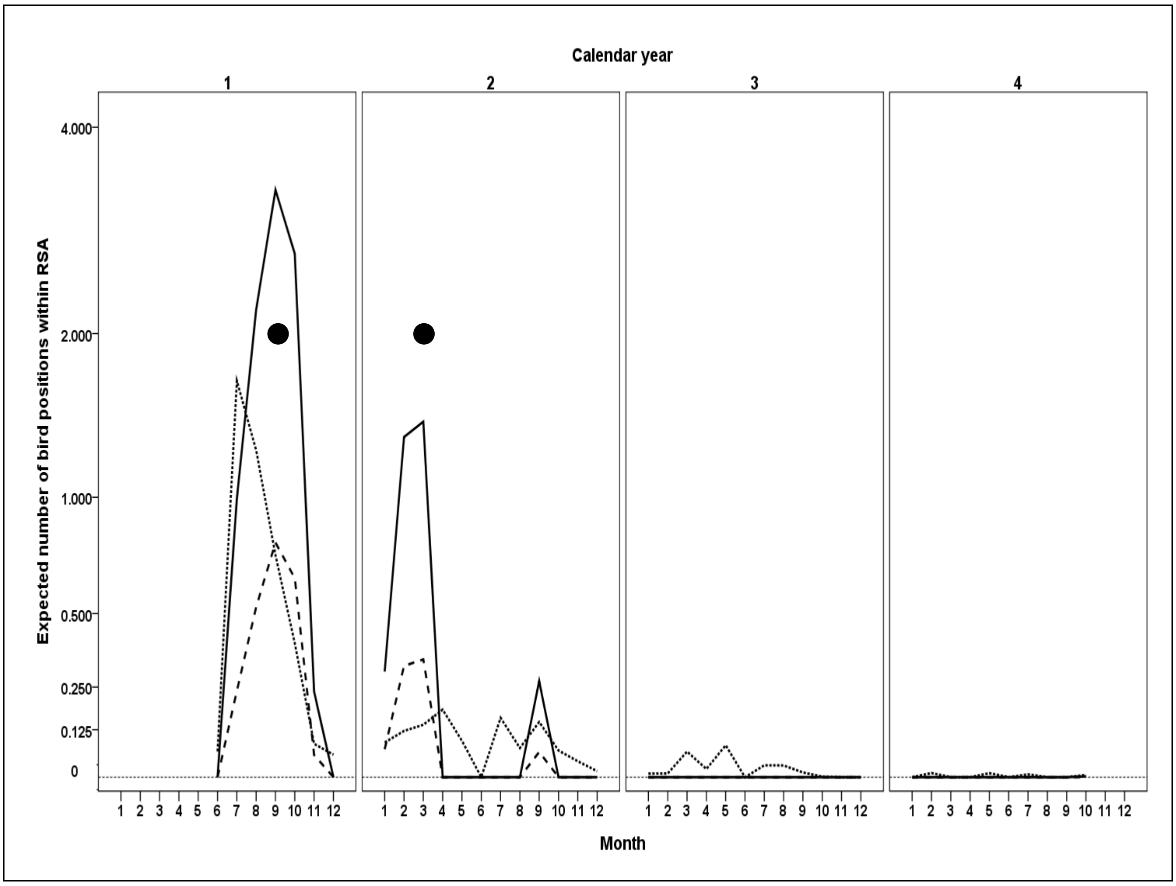


Figure 24. *Expected number of positions of satellite-tagged young WTE within the rotor-swept area at the SWPP by calendar year and month. Calculations were based on 50% kernel UDs (unadjusted for altitude = solid line, adjusted = open dashed line) and 95% kernel UDs adjusted for altitude (= densely dashed line). Actual recorded kills of tagged birds are shown as black dots. Note that the number of birds with working tags is decreasing with age, so the graph does not indicate individual risk rate over time*.

The method seems to be able to correctly identify the periods of the year and age-classes associated with the greatest hazard rate, judged from the recorded casualties. Calculations based on the unadjusted 50% UDs seemed to be the best predictor. It is worth noting that no avoidance rate was assumed, and that no adults were included. The widely used Band method for collision risk assessment (Band et al. 2007) is often used in conjunction with an avoidance factor based on observations and recorded kills. We did not attempt to calculate an avoidance rate, as sufficient observational data from the field were not available (but see May et al. 2010). Furthermore, the number of moves per day was based on estimations, and any movement may involve a combination of circling and directional flight at different altitudes, and could involve risks connected with several of the 68 turbines. One should also keep in mind that the studied birds had an affinity to the area, being their natal place. Thus, our findings are probably only typical to juvenile WTE relatively close to their natal area; nevertheless, they are relevant for large parts of the Norwegian coast. Displacement was probably negligible or small, as all birds were born within or close to the wind-power plant. On this basis, we suggest that the proposed avoidance rate proposed for golden eagles (ca. 99%) at other wind-power plants (Whitfield 2009) is not applicable to WTE in connection with wind-power plants close to their breeding sites. We are currently developing other risk assessment methods based on GPS position data using the method of 'Brownian bridges' (May & Nygård 2009) and by using ground-truthed bird radar tracks.

Studies on Smøla have shown that WTEs seem to use the air space inside and outside the wind-power plant area similarly (Lund-Hoel 2009). Several observers have noted that WTEs at Smøla often circle close to and around turbines, possibly induced by the extra wind energy created by the turbulence. The satellite-tagged victims were either killed in the first autumn (two in September) or in the following spring (two in April). The first autumn incidents may be influenced by lack of agility and experience, their naivety making them more prone to collisions. The incidents during spring in their second calendar year coincide with an overall greater turbine-related mortality rate during spring of all age-classes, possibly caused by increased territorial activity and good thermal conditions.

A Kaplan–Meier survival analysis showed that the additional mortality caused by the SWPP was ca. 10%, reducing the cumulative survival through their third year of life from 0.84 to 0.74. A full population model including adults is now under way, involving the use of DNA-analysis of moulted feathers from nesting pairs to estimate adult turnover rates.

5.1.2 Estimating collision risk

Subproject responsibility: Roel May

Large soaring birds of prey, such as WTE, are recognised to be perhaps the most vulnerable for collisions with turbines in wind-power plants. These mortalities have called for methods capable of modelling collision risks in connection with the planning of new wind-power developments. One model has been developed that has been widely used, the so-called “Band model”. This method is based on 1) estimating collision risk based on the calculated likelihood of a bird being hit by the rotor blades given that it passes through the rotor-swept zone (RSZ), multiplied by 2) the estimated number of birds flying through the RSZ throughout a given time unit (Band et al. 2007). The first step is based on the technical specifications of the turbines and the morphology, wing aspect, speed and flight behaviour (flapping or soaring) of the bird, while the second step involves the use of field observations. While the first step is quite straightforward, the second is prone to many potential sources of error and variations, involving observer skills, time of year, species-specific differences, precipitation, wind speeds, and so on.

Based on vantage point (VP) observation data from mid-March through the end of May 2008, the so-called “avoidance rate” (i.e. correction factor) for the Band collision risk model was estimated (May et al. 2010). Flight activity was calculated for each observation session at each VP separately. We tested thereafter for possible effects of time-of-day, week and placement (inside or outside the wind-power plant). The data indicated no significant difference between VPs placed outside the wind-power plant versus those placed inside. In other words, white-tailed eagles did not show different flight activity in either area. The data did, however, show a significant variation in flight activity over the day and over weeks. Using the pooled data, the correction factor used to calibrate the Band-model outcomes, was for WTEs 0.924 ± 0.098 (SD) (**Figure 25**). A similar modelling exercise will be done using the GPS-satellite telemetry data.

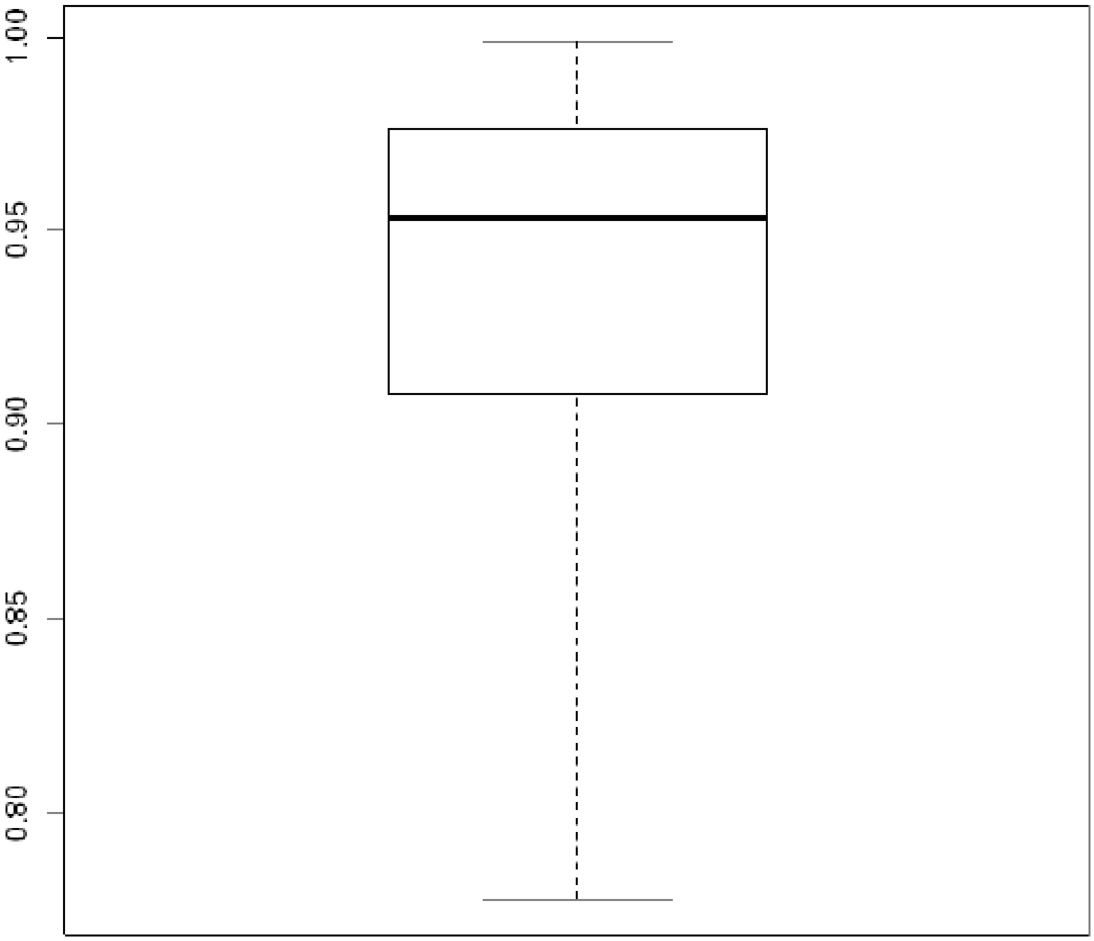


Figure 25. *Box plot showing the correction factor for the collision-risk model. The box indicates the 25th and 75th percentile; while the whiskers indicate the 5th and 95th percentile. The thick line indicates the median (50th percentile), whereas the dots indicate outliers.*

Given the lack of significant differences in flight activity inside versus outside the SWPP area, the estimated correction factor therefore does not signify displacement or (large-scale) avoidance as often stated. It may however, relate to other sources of bias, such as observer bias, and terrain and weather conditions. To avoid the biases inherent to the Band-model, we here propose a method which makes use of the data delivered by the birds themselves, through the use of GPS satellite telemetry. An attempt to quantify the risk of juvenile tagged birds of being hit by rotors has been performed on the GPS data using a new statistical approach - “Brownian bridges”.

Based on the GPS-data from the marked juvenile WTE, their susceptibility to collide with wind turbines was analyzed. This analysis was based on Brownian-bridge interpolation simulations, and render insight into the risk rates (i.e. time spent within ‘risky’ areas relative to the total amount of time) in time and space. The analysis, due to be sent in a peer-review journal shortly, presents risk rates for the time spent within the wind-power plant, and within the vicinity of the wind turbines (i.e. within a circular buffer of ca. 40 m). This analysis may thus render insight into periods (**Figure 26**) and areas (**Figure 27**) with heightened risk. This modelling approach can be utilized to direct mitigation measures in a wind-power plant when telemetry data is available; both in the pre- and post-construction phase.

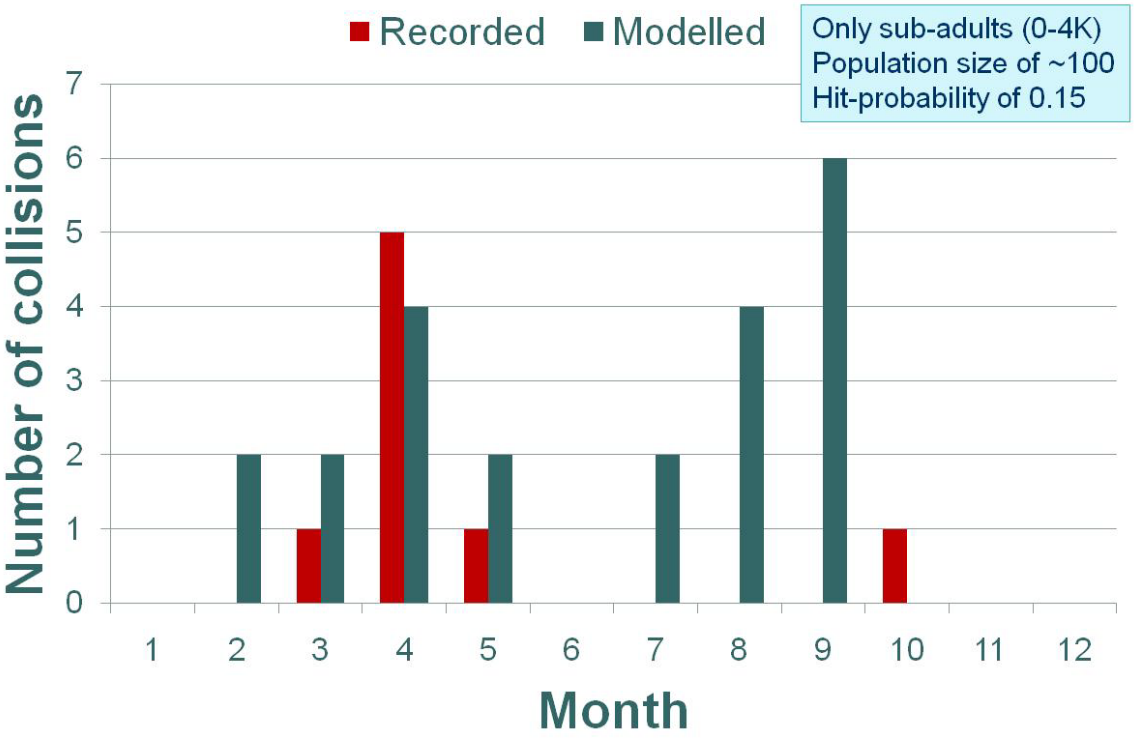


Figure 26. *Number of expected collisions derived from the 3D risk rates (i.e. amount of time spent within the rotor swept zone (29-111 m)) of sub-adult white-tailed eagles within the Smøla wind-power plant in Central-Norway (green), versus the recorded WTE collisions within the SWPP in Central Norway per age class (01.08.2005 – 01.10.2009) (red) over months.*

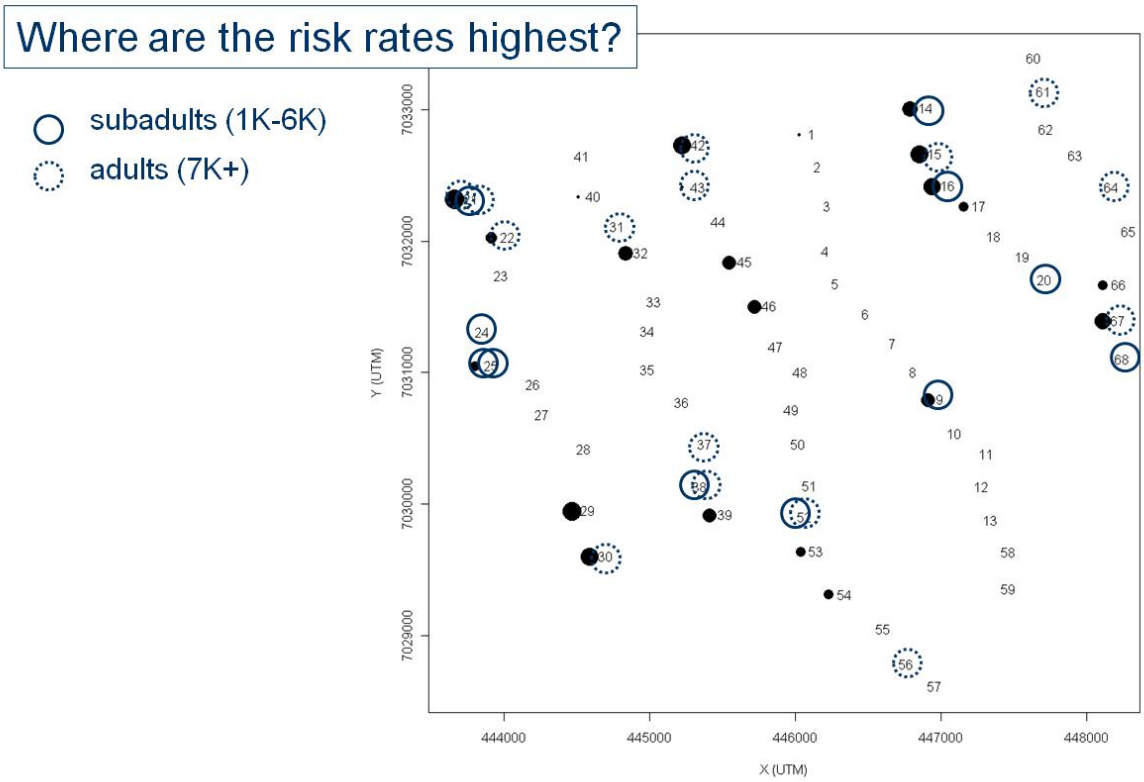


Figure 27. *Spatial representation of the relative (log-transformed) 3D collision risk rates per wind turbine within the Smøla wind-power plant in Central Norway. The numbers depict the turbine numbers while the size of the black dots indicate the risk (no dot equals no risk, while larger dots indicate increased risk). Turbine numbers with solid and dotted circles indicate recorded sub-adult and adult collision victims, respectively (each circle indicates one victim).*

5.1.3 Movements of juvenile white-tailed eagle

Subproject responsibility: Torgeir Nygård

Nine juvenile WTEs were tagged with GPS-transmitters on Smøla in 2010, of a total of 59 during 2003–2010. Eight were retrieval tags of the drop-off type. Only three of these were subsequently retrieved for data processing (2003-2004), and this type has not been used since. 51 were of the type that relayed their GPS-positions to a satellite system (Argos). Twelve were battery-powered, while 39 were powered by solar-cells. During 2005-2010, four of the tagged birds were recorded as killed by the turbines, while one was killed by electrocution at Hitra.

The pattern that was revealed earlier, showing that females move further away and further north during summer, still holds and is strengthened (**Figure 28**). Both sexes return to the Smøla region in general during autumn, and disperse again during the next spring/summer.

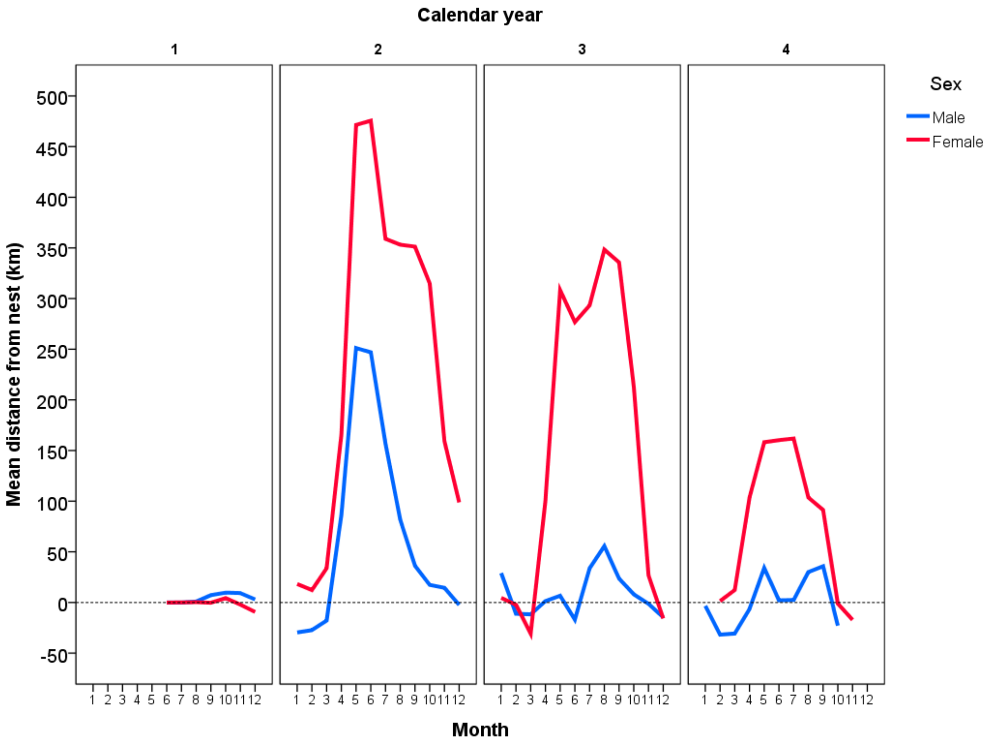


Figure 28. *Movements of juvenile white-tailed eagles satellite-tagged on Smøla, shown as average distance from nest per individual by month and calendar year. Negative values indicate movements to the south, positive to the north.*

Few movements in the southerly direction were recorded. Some inland movements occurred, even deep into the central Jotunheimen mountain-range and into Sweden and Finland. However, the majority of the positions are from the local region around Smøla, Hitra and Frøya, and to the north on the coast all the way up to North Cape (**Figure 29**).

On the average, juveniles of both sexes had dispersed more than one km from the tagging site (the nest) by August 18. Males were on the average dispersed more than five km from the natal site by August 26, and females by September 5.

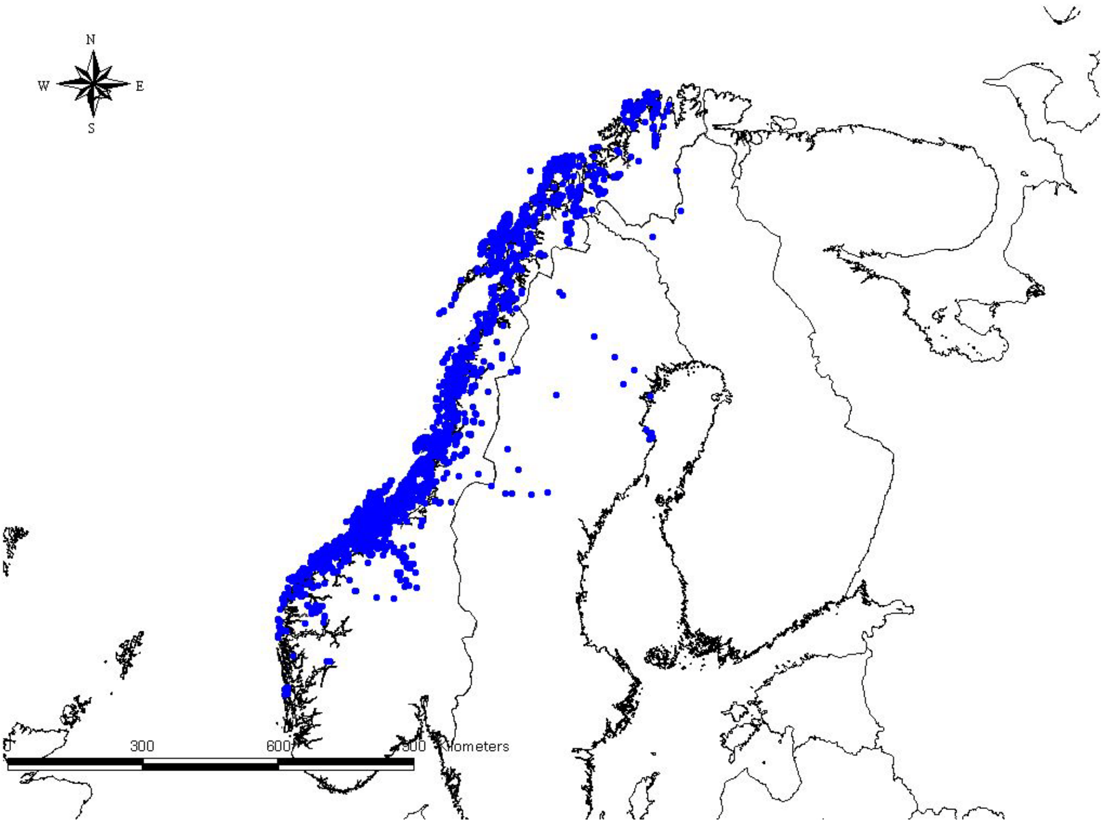


Figure 29. *Positions of all satellite-tagged juvenile white-tailed eagles on Smøla, showing one position per day per bird.*

5.1.4 Use of night-roosts

Night roosts have been described as potential hazard areas for eagles when they are situated close to power lines (Mojica et al. 2009, Rollan et al. 2010). We examined the use of night-roosts of juvenile WTEs on Smøla, and investigated whether their positions and proximity to wind turbines could involve potential risks. We used GPS-positions of satellite-tagged eagles to examine this question. Only positions retrieved after December 1 the first calendar year, were used, as first year birds are attached to the nest area during their first autumn as long as they are fed by their parents. A total of 33 birds gave such data. A total of 52 major night-roosts were identified by means of subjective inspection of the map (**Figure 30**), choosing the sites which apparently had the highest density of night positions. A night position was defined as a position obtained between 19:00 and 05:00 hrs.

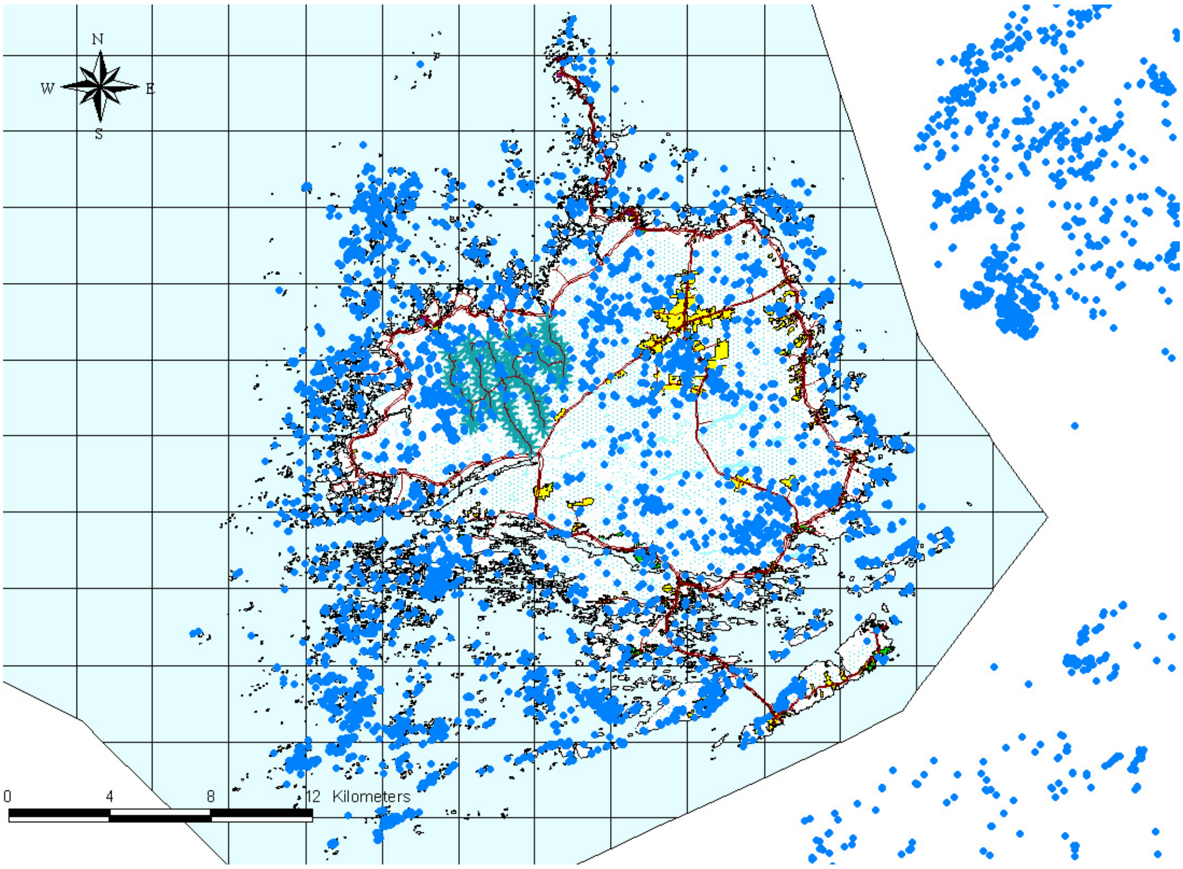


Figure 30. *Map of Smøla showing night positions (19:00 – 05:00) of juvenile satellite-tagged white-tailed eagles as blue dots. The wind turbines are indicated as green stars, farmed areas as yellow.*

Of the 10,923 positions recorded during night-time within the Smøla municipality (blue-shaded area, **Figure 30**), 6,237 (57%) were located within the 52 areas judged as important night-roosts. These had an approximate area of 15 km^2, out of Smøla's total land area of 274 km^2, i.e. ca. 5%.

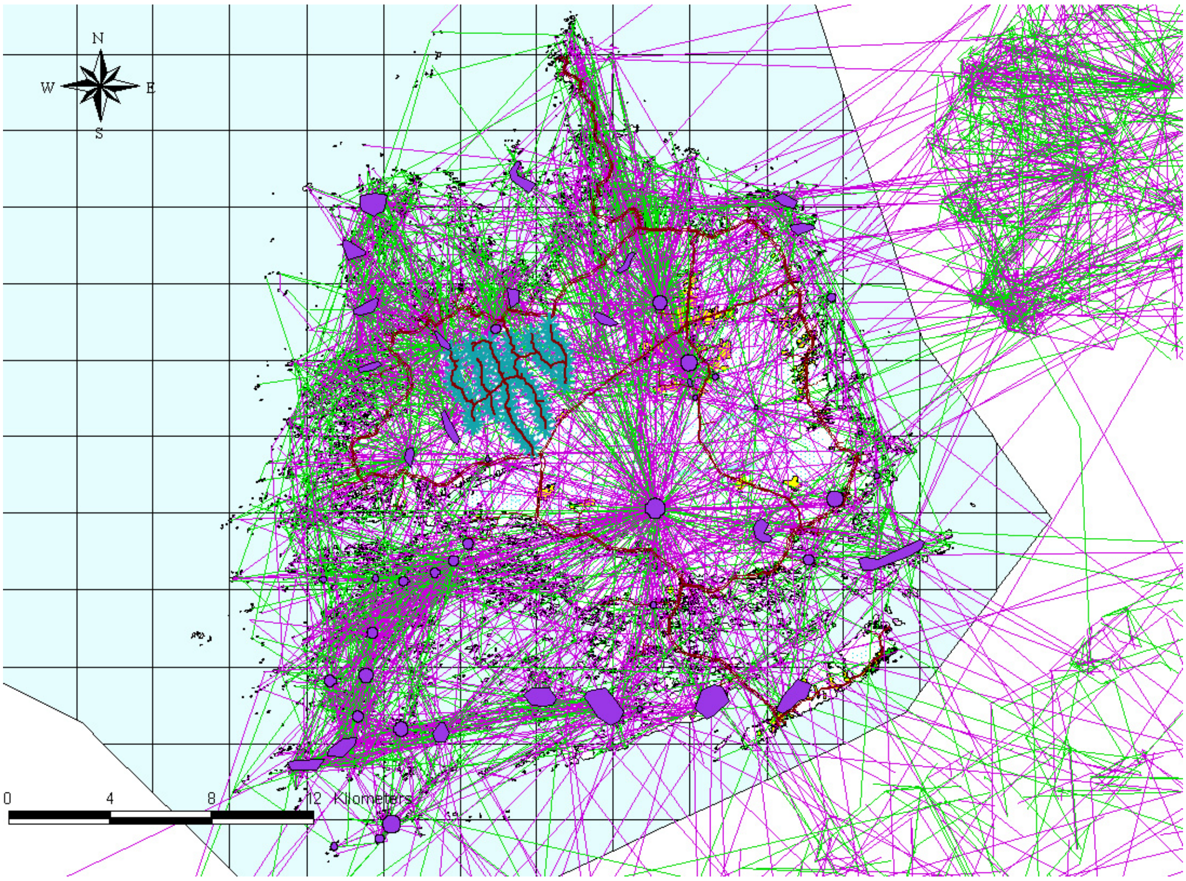


Figure 31. *The traffic of juvenile white-tailed eagles showed as lines between the nigh roosts and the daytime areas. Green lines represent movements during the morning (04:00-08:00), while purple lines represent evening movements (16:00-20:00). The main night roosts are shown as purple-shaded areas.*

Although drawn as straight lines **(Figure 31)**, the traffic in and out of the night roosts is not necessarily linear, the lines on the map are just connections between consecutive points in time by single birds. Lines through the SWPP area do not necessarily mean that birds have flown through it, as there are possibilities to fly around. Nevertheless, some clear patterns emerge. Some night roosts are more used than others, and some flight corridors seem evident. One night roost (the Maurdalen forest in the central island, with traffic in all directions, **Figure 32)**, and the areas west of the main agricultural areas of Frostaheia, showing clear movement patterns to and from the shallow archipelago in the far north (Veiholmen).

In addition to the major night roosts in the central parts of the island, there is also an obvious concentration in the archipelago in the south and southwest, and on the islands to the northwest of the SWPP, in the Dyrnes area. Two forest patches close to turbines numbers 21 and 42, respectively, north-west and north of the SWPP area are also major roosts. There is a noticeable lack of night positions in the west and the east, as well in the Veiholmen area. These areas seem to function as almost pure day areas, probably as feeding-grounds. Many of the roosts are in forest patches, but not all.

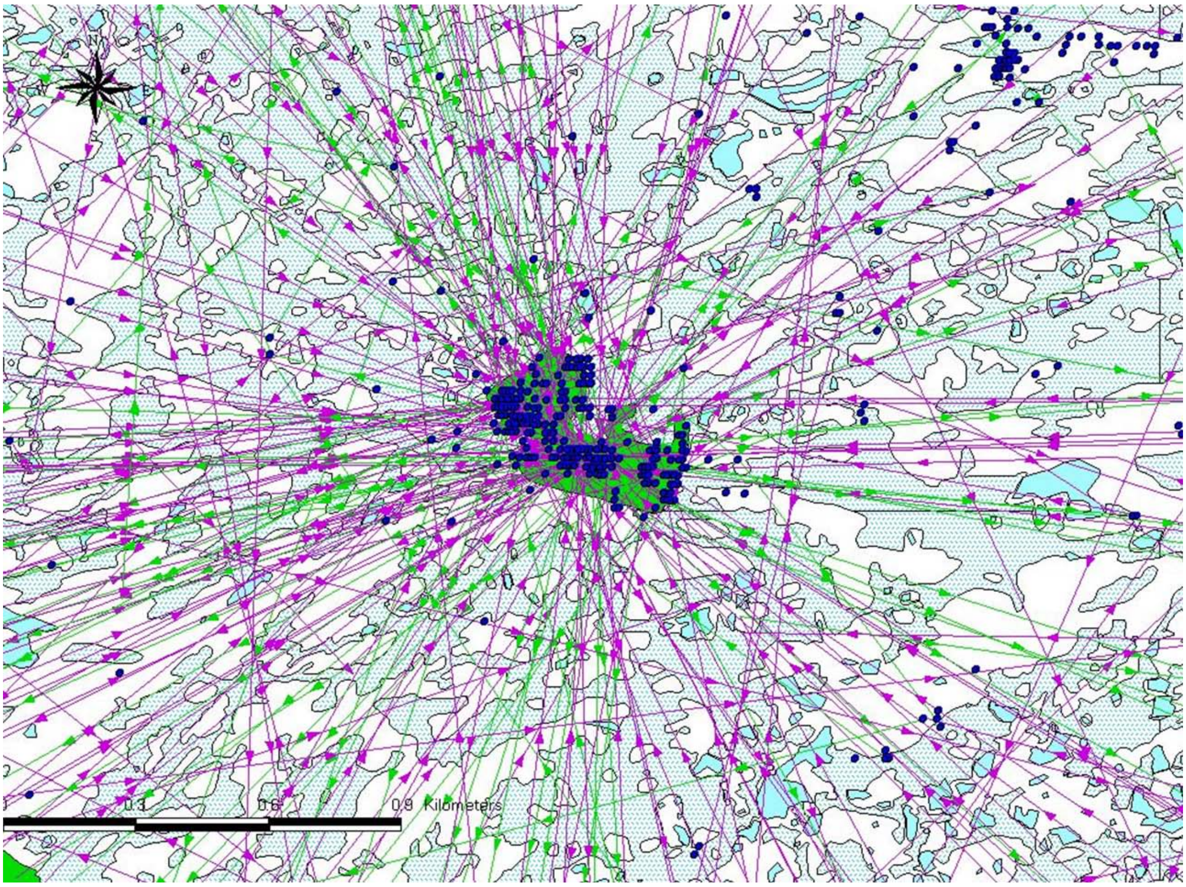


Figure 32. *Night positions at Maurdalen, central Smøla, and lines connecting consecutive positions between day and night. This is probably the most important night-roost of juvenile white-tailed eagles on Smøla, containing 512 GPS-positions. Green shaded areas are forest, dotted blue areas are bogs.*

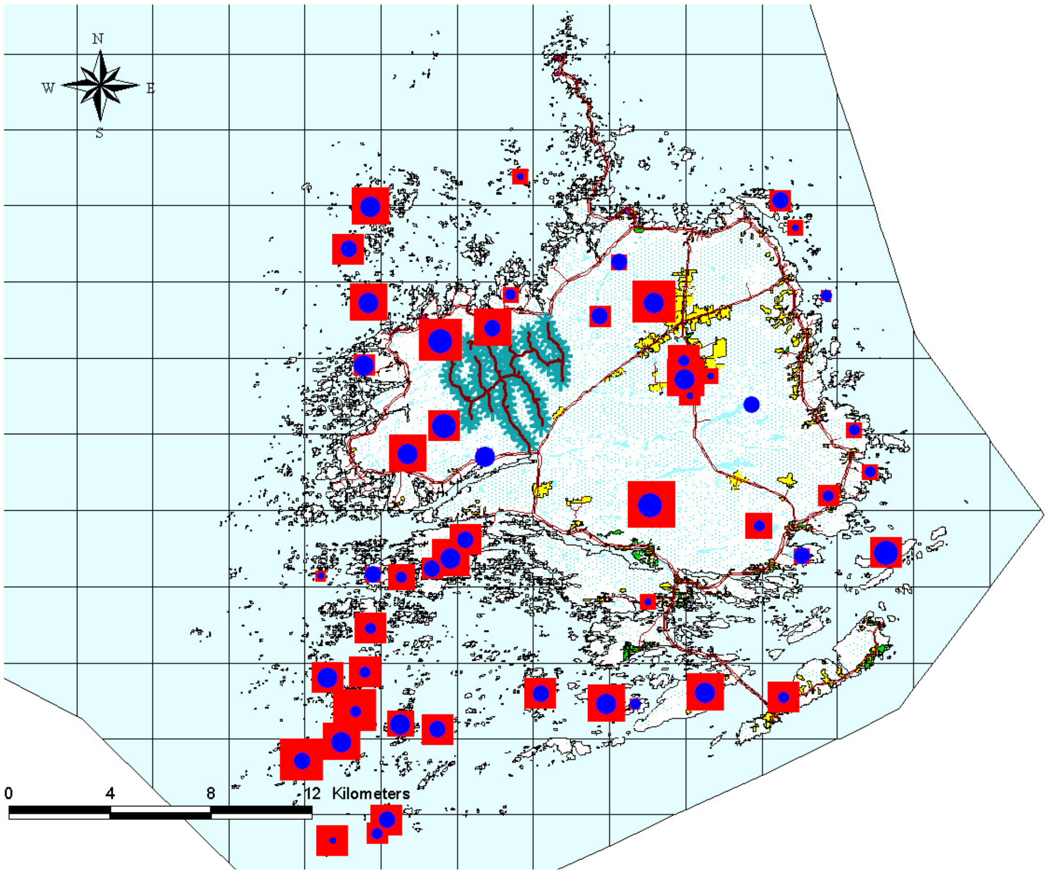


Figure 33. *The main night roosts of juvenile white-tailed eagles on Smøla. The size of the red squares indicate the size of the roost shown by the number of night positions recorded (from 20 to 512), and the size of the blue circles indicates the number of bird having visited the roost at least once (from two to 15).*

Some roosts were used by many birds (up to 15), and contained many positions, while some contained many positions from a smaller number of birds, and there were all kinds of variations. The importance of the roost in the south-western archipelago, in the middle of the island, and in the northwest, are clearly shown in **Figure 33**. Near the SWPP, the roosts north of the power plant are noticeable; especially the one close to turbine 21 and 22 in the north-western corner (having been known for many years among ornithologists), and the one centrally in the north (close to turbine 42 and 1). Together, these have had nine casualties of eagles, and one may speculate whether these were connected to traffic in and out of the night-roosts. It is well known that utility structures pose hazards to large raptors when they are in important flight corridors (Ariza 1998, Mojica et al. 2009), and the same has been documented for wind turbines in areas of high concentrations of soaring or feeding raptors (Barrios & Rodriguez 2007, Farfan et al. 2009, Smallwood & Thelander 2008).

The WTEs will necessarily use low altitudes during their flights in and out of the night roosts. If the night roosts are close to the SWPP area, this might pose a hazard. These patterns are important to take into account when planning wind-power plants, and pre-construction knowledge of such roost should be obtained during the planning process. If the plans for a stage three of the SWPP is to be realised, such data are now available. It might be more than a coincidence that nine out of 39 (23%) of the WTEs killings caused by turbines on Smøla have occurred at four turbines close to night roost.

5.1.5 Satellite tagging of adults

As a majority of the eagles killed by the SWPP turbines are adults, an important step towards understanding of the behaviour of the adult territorial birds in SWPP area would be to catch and GPS-tag such birds. An attempt to capture and satellite-tag local breeding adult eagles within the SWPP was done in January/February 2010, by use of a remotely controlled cannon-net at a bait of carcasses monitored by a web-camera. The attempt failed, and there could be several reasons for that. The exceptionally cold winter, with temperatures reaching record lows of down to -25°C, may be one of the reasons. Very few eagles were observed in the SWPP area during this cold period, but there was some feeding activity at the carcass during short periods, when the station unfortunately was not manned by personnel from NINA. However, we feel confident that we will succeed in the end, and increased efforts to catch adult birds for satellite telemetry are planned. This involves the use of an extra feeding-station equipped with a new remotely controlled cannon-net developed in the USA (**Figure 34**).

New transmitters based on GPS/GSM technology from Cellular Tracking Technologies LLC, Pennsylvania, USA will be used, and these have the capacity to obtain a GPS every 30th second, providing an accuracy of eagle movement paths that have not been possible earlier.

Figure 34. *The constructor of the “Net-launcher”, Bryan Bedrosian, fires the cannon-net at a demonstration in Fort Collins, Colorado, USA, in September 2010.* Photo: Torgeir Nygård.

5.1.6 Preliminary conclusions and remaining questions

Conclusions:

1) GPS satellite telemetry on juvenile white-tailed sea eagles has rendered detailed insight into their behaviour within and outside the wind-power plant. A probability analyses using GIS based on GPS-locations showed that their collision risk is highest during their first autumn

and during spring in their second year. This coincides in time with the dates of the casualties of satellite-tagged birds.

2) A Kaplan-Meier survival analysis indicated that the cumulative survival of the satellite-tagged juveniles during their first three years of life was reduced by 10% due to wind power-plant related casualties.
3) Collision risk modelling has shown that white-tailed eagles are most prone during spring. Also the developed Brownian bridge methodology not only provides insight into temporal effects, it enables also the delineation of specific areas or indicating specific turbines with increased risk.
4) The juveniles show a cyclic movement pattern, involving dispersal during summer, mainly to the north, and a return movement to the area they were born in the spring, with a new movement away during the next spring. Over years, they seem to be more and more attached to their region of birth. Females move further than males.
5) Their movements along the coast involves visiting many potential future sites for wind-power development, which illustrates the possible nation-wide scale of cumulative effects; any young white-tailed eagle born along the coast has a potential chance of entering any planned and existing wind-power plant along the Norwegian coast.
6) Two large night-roosts close to the turbines in the north-western part of the Smøla wind-power plant indicate a connection between the use of these and the high collision rates at these turbines.

Remaining questions:

1) Our findings show that the majority of the white-tailed eagles killed by turbines on Smøla are adult birds. A priority should be to trap territorial breeding birds within and close to the wind-power plant to reveal their detailed movement patters within the wind-power plant in order to assess their collision risk.
2) Many of the satellite-tagged birds still survive wearing active GPS-tags, and it should be a priority to follow them further throughout their lives to gain more knowledge of their movement patterns and survival.
3) Central to collision-risk modelling is the possible effect avoidance behaviour may have to reduce the number of casualties. Avoidance behaviour may include both displacement effects (i.e. where the wind-power plant is no longer perceived as habitat) and behavioural responses at different spatial scales (avoidance of the wind-power plant, a specific turbine or last-second avoidance of moving rotor blades). This should receive more focus in the future.

5.2 Genetic analyses

Subproject responsibility: Arne Follestad, Øystein Flagstad

Objectives: To estimate adult mortality among breeders in, or close to, the SWPP based on DNA-analyses of moulted feathers from adult birds and plucked feathers from chicks at the nesting sites.

5.2.1 Description of work

In this subproject we use DNA-analysis to determine the territory structure in the WTE population at Smøla. DNA-based individual identification of moulted feathers from adult birds at the nesting sites allows identification of the different territories, which in turn provides an accurate estimate of the number of breeding pairs in the population (see **Figure 35**). In this way we can follow the breeding pairs from year to year and monitor shifts or turnover of breeding birds. The white-tailed eagle is considered to be highly faithful to its partner and a shift of one of the adult birds in a territory should therefore be interpreted as mortality. Plucked feathers from chicks at the nesting sites are used to confirm apparent adult mortality. Finally, comparison to the DNA-profiles of eagles that have been killed by collisions in the wind-power plant allows us to separate the wind power related mortality from the background mortality in a natural WTE population.

In the period 2006-2010, we have built a time series database that covers most breeding WTE pairs on Smøla. The time series data in and close to the SWPP provide a unique possibility to estimate WTE adult mortality, and model how the extra mortality caused by the power plant affects the population growth rate. The observed mortality in the SWPP will be compared to the mortality among breeders at increasing distance from the power plant as well as mortality in a control population not influenced by wind power development.

Figure 35 *Two pairs of nesting localities that from observations alone were considered to be four separate localities. DNA-analysis of moulted feathers of adult eagles shows that these two pairs of localities represent only two territories.*

5.2.2 Optimization of methods

For increased efficiency in the laboratory and to streamline the production of DNA-data a robot was used to extract DNA. In comparison to the previous manual extraction protocol this has increased the success rate for DNA-profiling of individual samples, which is now higher than 90%. Moreover, the implementation of the automated extraction protocol allows a highly reduced handling time for each sample, which in turn contributes to efficient production of reliable DNA-profiles.

Efforts have also been made to develop efficient methods for DNA-profiling and sex determination. A panel of 12 microsatellite markers that are highly polymorphic in the population on Smøla was selected after testing. A multiplex PCR set-up has been developed to ensure efficient data production (**Figure 36a**). Our original protocol for sex determination was designed to handle relatively long DNA-fragments, and the templates from some of the moulted feathers were too degraded to be reliably analyzed. We now follow the ARMS method described in Ito et al. (2003), specially developed for birds belonging to the family Accipitridae, which is the case for the WTE. This protocol is designed to handle shorter DNA-fragments and is ideal for partly degraded samples such as moulted feathers (**Figure 36b**).

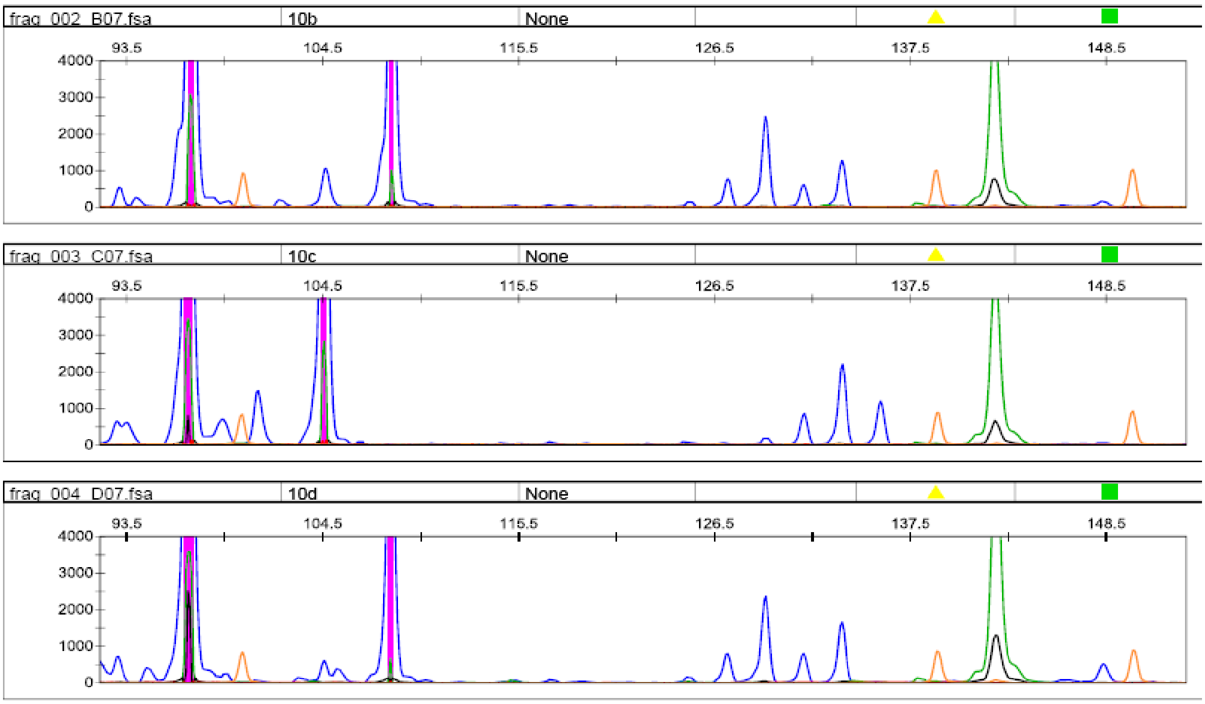


Figure 36a *DNA-profiles from one multiplex PCR mix consisting of three different markers. The example shows three analysed feathers at one nesting locality. The three profiles represent two different individuals.*

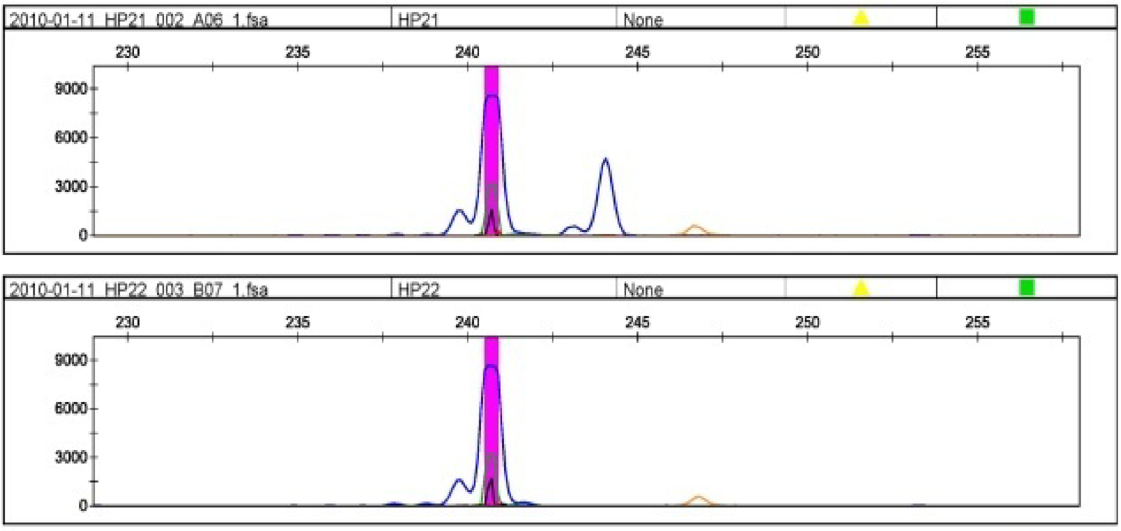


Figure 36b *Visualization of sex determination using the ARMS method, which were found to work excellently for our feather samples. The upper replicate represents a female, which has two different alleles on the target loci, located on the Z and W chromosome, respectively. The lower replicate represents a male, which has two identical copies of the target locus on the Z chromosome.*

5.2.3 Results

Number of active territories
The 82 nesting localities from which we have collected feathers represent 48 active territories, which is close to 100% of the known active territories on Smøla. A direct implication of these findings is that the number of active WTE territories has been overestimated from observations by approximately 15% (see **Figure 36**). This demonstrates the importance of conducting DNA-analysis along with other methods when estimating the breeding population size for the WTE.

Turnover/adult mortality within the territories
From the analyses conducted in the period 2006-2010, we have documented eight certain instances where one of the birds in a breeding pair has been replaced. In five of these instances, the bird that was replaced was found killed by a wind turbine, whereas other mortality factors may have influenced the three other replacements.

From these results, it seems that the wind-power plant constitutes an important mortality factor for the WTE population at Smøla, accounting for more than 50 % of the detectable adult mortality. However, it should be noted that these figures are highly preliminary. A more sophisticated statistical approach including data from adult birds, chicks on the nests and birds killed in collisions with wind turbines is needed to be able to quantify the mortality rate in the breeding WTE population and the potential negative effect of the wind-power plant.

Tracing the origin of the dead eagles found in the wind-power plant
Thirty-nine white-tailed eagles have been found killed in the power plant since search for dead birds was initiated in 2005. Thirty-three of these were killed in the period 2006-2010, which allows direct comparison to the reference material of moulted feathers collected in the breeding territories during the same period. Seventeen of these 33 eagles were adult birds, of which only five (~30%) are represented in our reference database of moulted feathers. This relatively low matching rate could partly be explained by a moderate sample coverage of the breeding pairs, especially the first 1-2 years (2006-2007). However, even in 2010, when we know that most of the breeding pairs are represented in our database of adult breeding birds, two of five adult birds that were killed in the power plant were not represented in the database.

These two birds and some of the other non-matches could represent adult eagles from other (sub)-populations, visiting the wind-power plant on Smøla. Considering the territorial behaviour of the WTE, such an explanation does not seem too likely, especially considering that most of the collisions take place in the middle of the breeding season for the species. Rather, we consider it far more probable that there may be a certain proportion of floaters in the WTE population on Smøla; i.e. eagles without a territory. As these birds are not connected to a territory they will not be represented in our DNA-database of territorial birds at Smøla.

Another important question that should be addressed from the origin of the dead eagles is whether the risk is higher for birds breeding within the wind-power plant as compared to birds breeding at increasing distance from the developed area. Indeed, our data seems to suggest that birds breeding within the wind-power plant are particularly vulnerable to wind power related mortality. Three of the five breeding birds that could be traced to our database of adult eagles were breeding within the power plant, whereas the two remaining bred on islands north of the Smøla mainland, 3-6 kilometres from the nearest wind turbine in the power plant. In addition, we have two instances from breeding territories within the park where one of the adults in the breeding pair has been replaced by a new bird. A plausible explanation is that also these two cases likely represent wind power related adult mortality.

5.2.4 Preliminary conclusions and remaining questions

Conclusions:

- DNA-sampling of moulted feathers has proven to be a cost-effective method for estimating the number of active territories within a wind-power plant. A simple survey of nesting sites may overestimate the number of breeding pairs; in our case by approximately 15%. This has important implications to the evaluation of the vulnerability of any WTE population.
- Development and optimization of the DNA-methods used herein have given us invaluable experience, which makes it easier to address similar questions also for other birds of prey.
- Preliminary results indicate that the wind-power plant constitutes an important mortality factor for the WTE population at Smøla, accounting for more than 50 % of the detectable adult mortality. In particular, birds breeding within or close to the wind-power plant seem to be especially vulnerable to wind power related mortality.
- A relatively large proportion of the adult eagles that have been found dead in the wind-power plant are not represented in our database of breeding pairs. This suggests that a certain proportion of adult eagles in the population are floaters that do not defend their own territory.

Remaining questions:

- The proportion of non-territorial adult birds or floaters in the population can be estimated by simulating the expected number of matches given the representation of known breeding birds in our database of adult eagles.
- The database, from which we monitor turnover and the origin of dead eagles, allows us to identify breeding territories that are particularly vulnerable to wind power caused mortality. Such knowledge is important for implementation of appropriate mitigation efforts that potentially can reduce the extra mortality imposed by the wind-power plant.
- During the project period we have generated a five years time series, from which adult mortality in the population can be formally estimated. However, the number of dead birds and matches to our database is still relatively low. Therefore, for more robust estimation of adult mortality the time series should be extended. This will allow us to model how the wind power related mortality affects the population growth rate. In addition, we recommend that a similar time series is generated for a control population which is not affected by wind power development. This will enable us to separate the wind power related mortality from the background mortality in a natural WTE population.

5.3 White-tailed eagle breeding success

Subproject responsibility: Espen Lie Dahl

Objectives: To monitor possible changes in the WTE-breeding population abundance on Smøla caused by the development of the wind-power plant, and study whether the plant has any short- or long-term effect on the eagles' reproduction and breeding success.

5.3.1 Description of work

Before construction of the SWPP there was concern connected to whether and how the dense WTE population breeding in the area would respond, therefore WTE population monitoring has been a central issue in the BirdWind project. A detailed monitoring scheme of the breeding population size and reproductive success was therefore established.

5.3.2 Activities and findings

The eagle population on Smøla has been closely monitored since 2002 when the power plant was constructed. The monitoring was further strengthened from 2006 onwards, when DNA-sampling of the population started, involving both adults and chicks (see 5.2). All eagle territories with all nest sites are surveyed every year to record the activity in every territory. A territory is recorded as active if there are traces of adult birds in the territory, i.e. moulted adult feathers at the nest, rebuilt nests, egg laying or production of chicks. In cases where there is doubt connected to whether neighbouring nests belong to the same or to different territories, breeding has to be recorded in both neighbouring nests in the same season to denote them as separate territories. DNA-sampling of feathers of young and adults at the nest sites allows us to further improve this method, as feather samples is sufficient to reveal the identity of the birds occupying the territories, making it easier to separate between different territories. The DNA-sampling also allows us to compare whether the same birds are occupying the different territories from year to year, as well as trace the origin of birds found dead in the SWPP.

For this report we aim to sum up the data sampling from the study area so far, both with respect to population trends and reproductive success and the wind-power plant's influence on the population size and reproduction size.

Terms and definitions (from Oehme 2003):

- A **territory** is an area containing one or more nests within the home range of a pair of mated adult eagles.
- An **occupied territory/occupied nest** has to match at least one of the following criteria:
  - Eggs or young in the nest
  - An adult eagle in an incubating position in the nest
  - An eagle pair on the nest or in the vicinity of the nest showing territorial activity (display flight, copulation, nest repair, nest defense etc.)
  - Clearly rebuilt nest
- To **avoid double counting of territories**, one has to consider the possibility that an eagle pair may rebuild more than one nest within its own area in the same breeding season.
- A **breeding attempt** is a pair of mated eagles trying to reproduce by laying eggs.
- **Successful breeding** is a breeding attempt producing one or more fledglings.
- **Reproductive rate** is the number of young per number of active territory within a breeding season.

5.3.2.1 Breeding survey and population monitoring 2002-2010

In 2010 51 active WTE territories were recorded in the municipality of Smøla. A total of 36 chicks were produced within these territories which is the highest number of chicks recorded ever on Smøla (**Figure 37)**. Within the SWPP area there was only one successful breeding attempt, producing one young. The implementation of the DNA-sampling allows us to make better estimates of number of active territories than before. Interestingly, results show that what was believed to be separate territories occupied by different adult eagle pairs, based on the previous established survey methods, are in several cases occupied by the same eagle pair. Thus, the previous survey methods has led to a "double-counting" error when counting the number of active territories/pairs each year, as nests separated by several kilometres are in some cases occupied by the same birds moving between the different nest sites between different years, crossing territories occupied by other birds. This means that the same adult pairs have, in several cases, been counted twice. This overestimation of the number of active territories is between 10-15% in the 2006-2010 period, i.e. the period when DNA-sampling has been conducted (**Figure 37)**. After correcting for the results from the DNA-sampling the number of active territories on Smøla in 2010 was 45, in contrast to 51 using the previous established methods. This emphasizes the importance of using sophisticated methods when conducting studies like this, and the findings are crucial for a precise modelling of the WTE population on Smøla. With the exception of 2004 the total number of active territories in the post-construction period is quite stable.

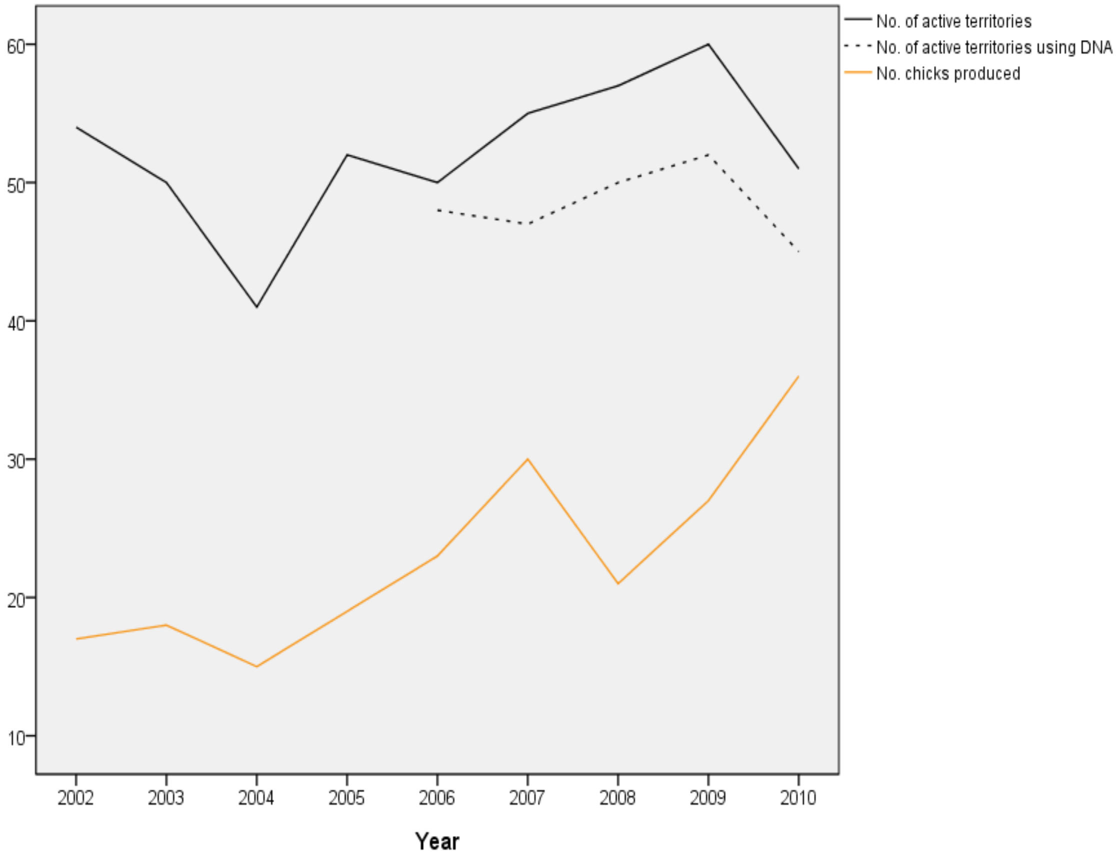


Figure 37. *The number of active white-tailed eagle territories and the number of chicks produced on Smøla in the post-construction period of the wind-power plant. The dashed line represents the number of active territories recorded using DNA-methods (corrected for double counting of territories) in the period 2006-2010.*

The real population size is very likely to be higher than the number of territories with confirmed activity each year. This is due to eagle pairs not breeding every year, and in the intermittent years the behaviour of pairs not breeding can be very inconspicuous. The actual population size will be revealed by the final genetic analyses. In addition to these territorial pairs comes an unknown number of "floaters", these are adult, or near adult birds, not paired up and established in own territories. This part of the population buffers the breeding population, filling in vacant territories when they become available. Hopefully, through intensive population monitoring combined with the DNA-sampling, we will be able to quantify this part of the eagle population also.

Figure 37 shows that the number of young produced in the post-construction period has had a positive trend with increasing number of young produced, with an all time high of 36 young in 2010. The reproductive rate throughout the post-construction period also shows a positive trend in the period with increasing number of young per active territory (**Figure 38**). These data suggest that the overall eagle population on Smøla is performing relatively well with respect to reproductive success at the time being.

The eagle population on Smøla is distributed throughout both the main island and in the surrounding archipelago. To see how the different sub-populations perform the territories are grouped into four groups; "windfarm" (territories with nest sites closer than 500 m from the closest turbine), "buffer" (territories with nest sites within 0.5 – 3 km from the closest turbine), "main island" (territories with nest sites on the main island of Smøla except "windfarm" and "buffer") and "archipelago" (territories with nest sites in the archipelago surrounding the main island) (see **Figure 38)**.

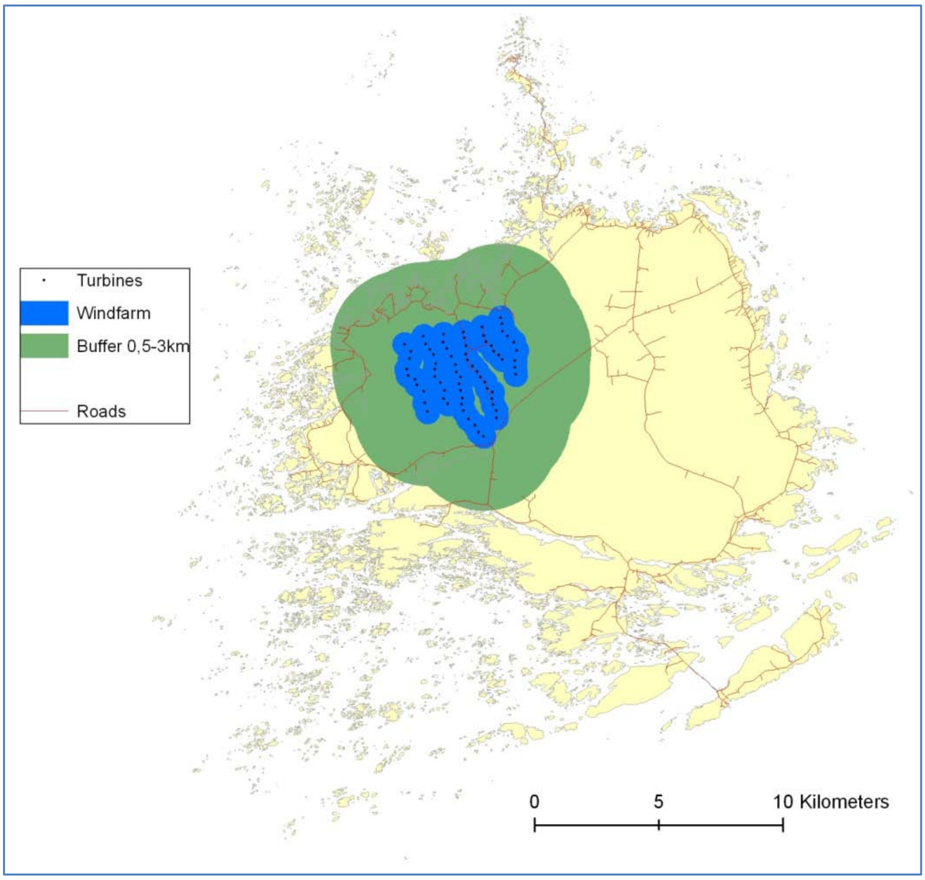


Figure 38. *Map of Smøla with roads, wind turbines, the "windfarm" area in blue (areas closer than 500 meters from nearest turbine) and the "buffer" zone in green (areas from 0.5 to 3 km from nearest turbine).*

Figure 39a shows the number of active territories throughout the post-construction period of 2002-2010 divided into these four sub-groups. Both the SWPP area and the main island have weak negative trends with decreasing number of active territories, whereas the buffer zone and the archipelago area has had a weak positive trend with increasing number of active territories during the period. Although none of the trends were significant, the findings the findings confirms the results from a density analyses (**Figure 39b**) where the density of occupied (active) WTE territories on Smøla in 2001-2002 was compared with the density of occupied territories in 2008-2009. Results showed that the density was higher within the SWPP area before construction of the wind-power plant compared to the period after. At the same time the density of occupied territories increased in the buffer zone to the southwest of the wind-power plant in the post-construction period. This analysis does not take into account the results from the DNA-sampling, because it would have made it difficult to match the results using old methods with the results from the DNA-sampling that started in 2006. The decreasing number of active territories within the SWPP area are probably do both mortality among territorial birds in the area (collisions with turbines) and displacement (birds moving out and establishing other places because of high disturbance in the area). This has also been confirmed from DNA-analyses.

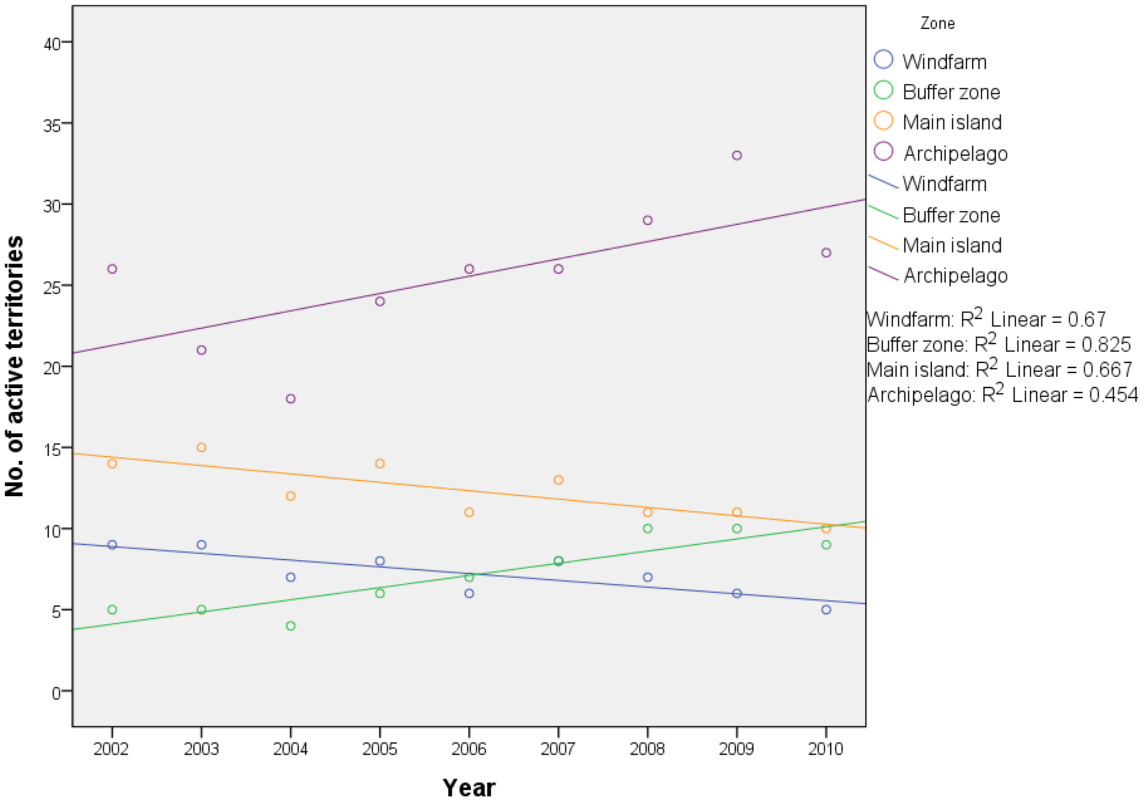


Figure 39a. *Number of active territories throughout the post-construction period of 2002-2010 in the sub-populations “windfarm” (territories with nest sites closer than 500 meters from closest turbine), “buffer zone” (territories with nest sites 0.5 km – 3 km from closest turbine), “main island” (territories with nest sites on the main island of Smøla except within the power plant area and the buffer zone) and “archipelago” (territories with nest sites in the archipelago surrounding the main island). This figure is based on the established methods and do* ***not*** *take into account results from the DNA-sampling that started in 2006.*

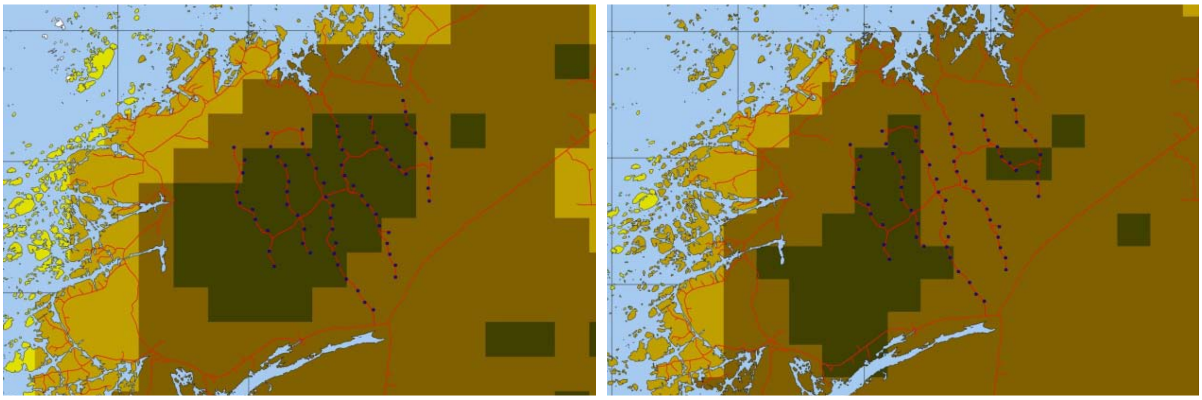


Figure 39b. *Densities of occupied white-tailed eagle territories inside and close to the Smøla Wind-Power Plant in 2000&2001 (left) and 2008&2009 (right) calculated using Harmonic Mean in ArcView GIS 3.3. Darker colour indicates higher territory density. Roads represented by red lines and turbines in SWPP by blue dots.*

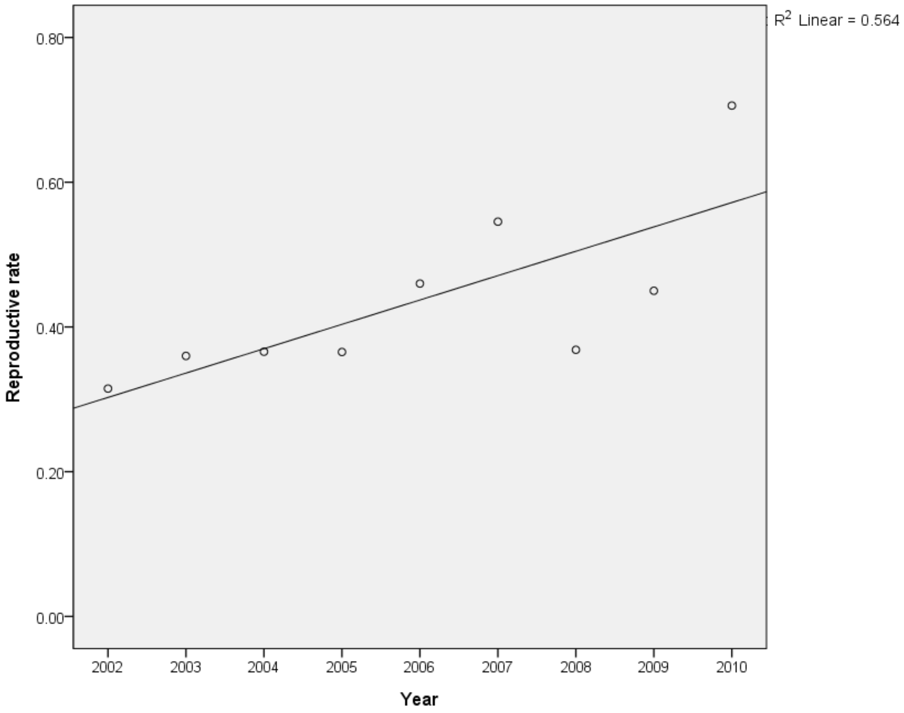


Figure 39c. *Reproductive rate (number of young/number of active territories) on Smøla in the post-construction period, 2002-2010.*

The overall reproductive rate (number of young/number of active territories) for the total WTE population on Smøla has had a positive trend, with an increasing reproductive rate throughout the study period (**figure 39c**). To see if the trend for reproductive rates are different in the wind-power plant area compared to other areas on Smøla the population were split into different sub-populations “windfarm”, “buffer zone”, “main island” and “archipelago” (**Figure 39d**). For this purpose the post-construction period was split into two periods; stage I (2002-2004) and post-construction (2005-2010). The pre-construction years 1999-2001 were also included in the analysis for comparison. The four sup-populations had quite similar mean reproductive rates in the pre-construction years 1999-2001. During stage I the buffer zone performed better than the other sub-populations, while in the post-construction period the archipelago performed better than the other areas. There is a slight negative trend, although not significant, when looking at the SWPP area across the different periods, with decreased mean reproductive rate in stage I and in the post-construction period compared to the pre-construction period. The reason for this trend inside the SWPP not being significant is probably due to the fact that several of the eagle territories have become empty in the SWPP area throughout the period. It should also be noted that there are few years included in the two first periods and low a number of active territories in some of the sub-populations.

Using a generalized linear mixed model an analyses of the effect of the SWPP on the WTE breeding success was made using both occupied (active) and empty territories (Dahl et al. in prep). A negative effect of the SWPP was found, where territories within the SWPP area before construction had a significantly higher proportion of successful breeding attempts than the same territories after construction (**Figure 40**). This effect was mainly due to territories being deserted within the SWPP area. The reason for territories being deserted could either be that birds occupying them were killed, or it could be disturbance leading to birds leaving their territories within the power-plant area. Most likely there is a mix of these factors leading to the decreased number of occupied territories in the SWPP area.

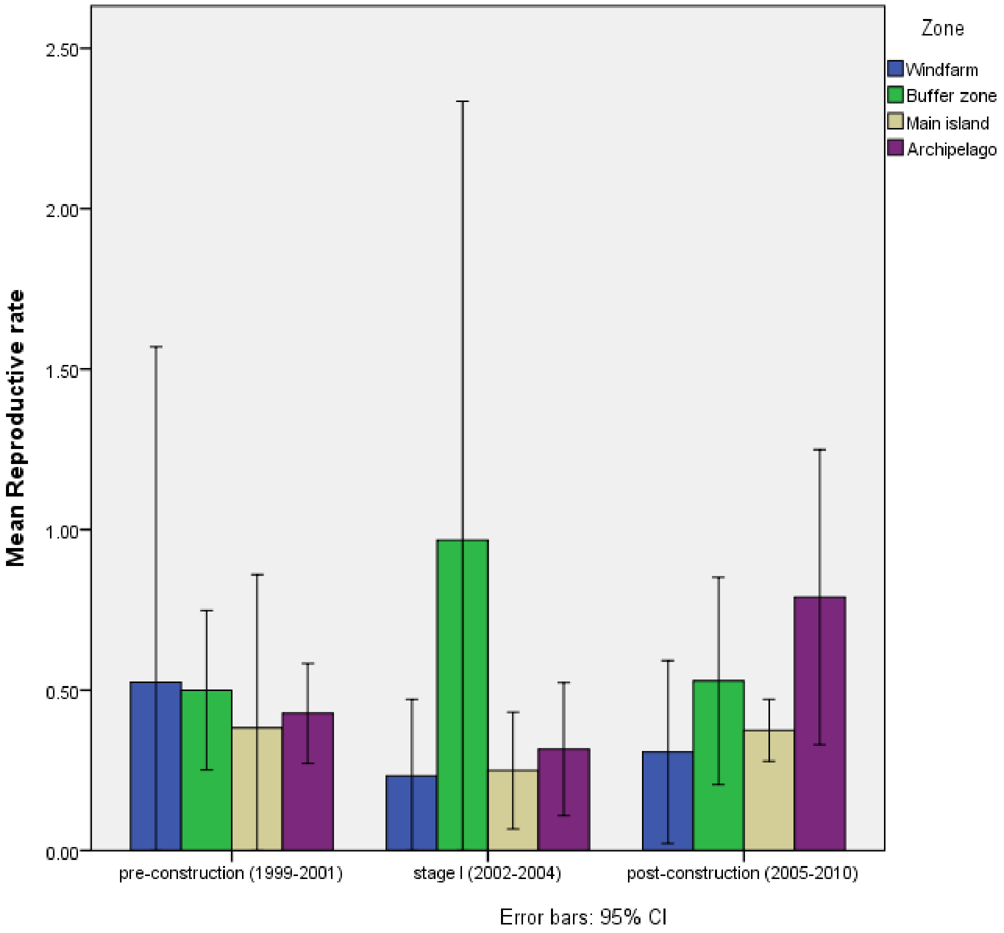


Figure 39d. *Mean reproductive rate for the sub-populations "windfarm", "buffer zone", "main island" and "archipelago" in the periods; pre-construction (1999-2001), stage I (2002-2004) and post-construction (2005-2010). The figure is based on the data sampled using the established methods, and does not take into account the results from the DNA-sampling initiated in 2006.*

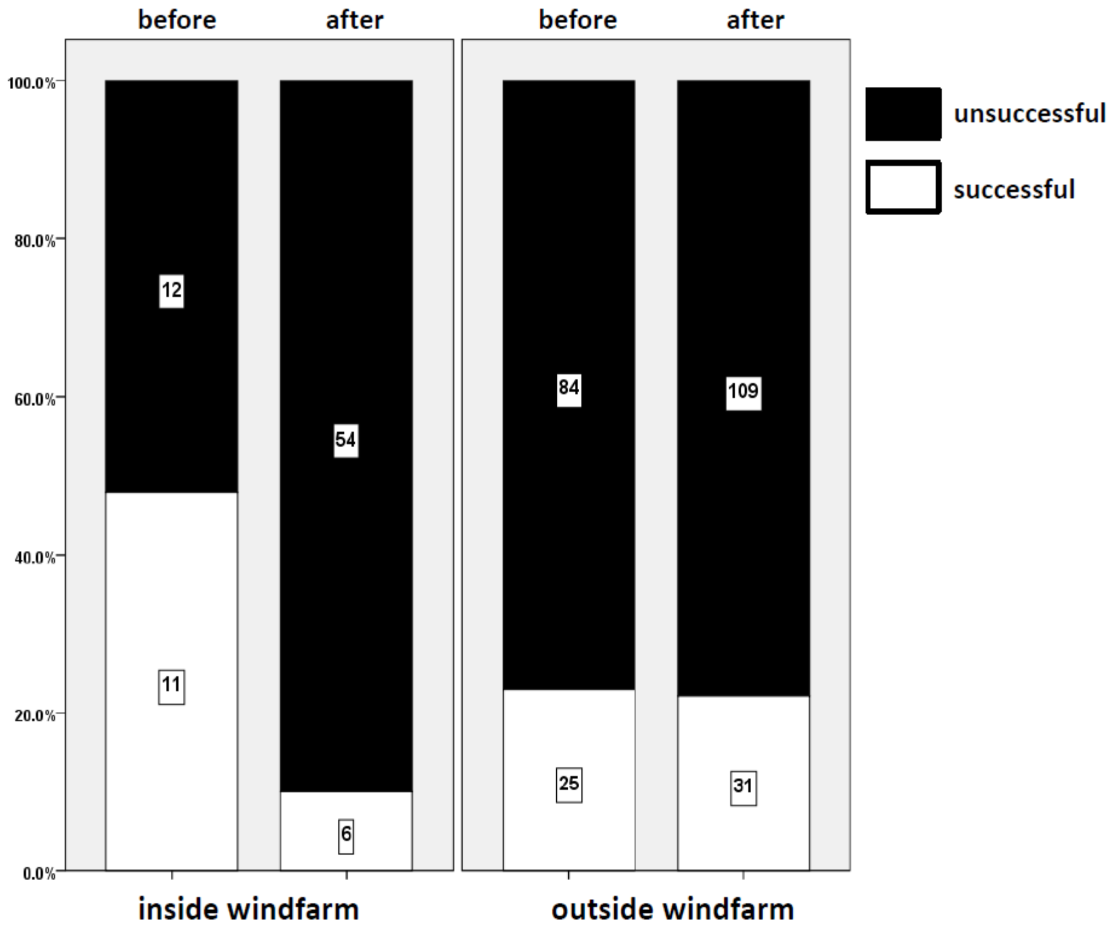


Figure 40. *Numbers and proportions of successful (dashed) and unsuccessful (black) breeding, inside and outside 500 m from the turbines within the Smøla wind-power plant area. The two left columns represents the area inside 500 m from the turbines, the two right columns represent the area on the main island of Smøla outside 500 m from the turbines. Number of cases in each category is given inside the columns.*

5.3.3 Preliminary conclusions and remaining questions

The overall population size of WTE on Smøla seems to be quite stable throughout the post-construction period of the SWPP, after a period with increasing population size prior to the establishment of the power-plant. The number of active territories within the SWPP area has decreased in the post-construction period, probably as a result of birds being killed by the turbines and increased disturbance leading to displacement of birds in the area. At the same time the number of active territories has increased in the buffer zone (0.5-3 km to nearest turbine) surrounding the power-plant. We were able to track, using DNA-sampling, at least one of the pairs holding territory within the SWPP area before construction leaving the area and establishing a new territory in the buffer zone. Further DNA-sampling of the population will give a better understanding and insight into these processes.

The number of young and the reproductive rate of the overall WTE population on Smøla have increased throughout the post-construction period. Looking at the SWPP area only, the situation is different. There are still a few active territories inside the SWPP area, and these territories has had a slightly negative trend, although not significant, with respect to reproductive rate when comparing the pre- with the post-construction period. This is probably due to the fact that several of the territories have been deserted throughout the period. When including the territories that has become empty (not occupied anymore), the results are significant, with decreased proportion of successful breeding attempts within the SWPP area in the period after construction compared to the period before.

The existing WTE population long-term data set on Smøla has made it possible to investigate the effects of constructing the SWPP, using a BACI (before-after-control-impact) approach. When studying a long-lived species like the WTE such long-term data series are crucial to be able to track changes in important population parameters (e.g. population size and reproductive rate). The implementation of the DNA-sampling has also been an essential new tool, without DNA-data we would not have been able to establish the origin of collision victims, trace displaced adult pairs and avoid double counting of territories. After several years of data sampling we have an increasingly firm basement for estimating the reproductive rates of the WTE on Smøla. Future analysis will focus on mortality and turnover rates in the population using the DNA-data sampled over a 5 year period.

Conclusions:

- The overall population on Smøla is stable
- A decreasing population inside wind-power plant area is due to mortality and displacement
- An overall increasing number of young and reproductive success has been observed on Smøla throughout the study period (2002-2010)
- A decreasing number of young and reproductive rate is observed inside the SWPP area
- DNA s a very important contribution in the monitoring increasing the accuracy of the data
- Traditional methods overestimated population size with 10-15% compared to DNA-methods
- BACI (before-after-control-impact) is important when studying WTE population trends

Remaining questions:

- Analyse adult mortality/turnover rates in population based on DNA-monitoring (already started, finished spring 2011)
- Calculate actual number of eagles present on Smøla based in DNA-findings (planned finished 2011)
- Model long-term population effects (planned finished 2012 according to PhD plan Espen Lie Dahl)

5.4 Necropsy of white-tailed eagle

Subproject responsibility: Finn Berntsen

Objectives: To identify the cause of death based on inner/outer injuries on dead WTEs recorded in connection with wind turbines, and identify characteristics of lethal wind-turbine imposed injuries.

5.4.1 Material and methods

From August 2005 until September 2010, 44 adult dead WTEs have been recorded in connection with wind turbines in the Smøla and Hitra wind-power plants, 39 and 5 specimens respectively. The eagles from Hitra were collected in 2006, 2008 and April–November 2009. Three of the five Hitra specimens are included in the study. Eagles found before 2007 have been examined earlier (Follestad et al. 2007). The carcasses were of different value for post-mortem examination. Some specimen had been killed quite recently, while others were more or less free of soft tissue and quite desiccated. Thus, the condition of a majority of the carcasses did not allow for a thorough and classic autopsy. Nevertheless, all eagles were x-rayed. The objective of the x-ray picture examination was to reveal fractures of the skeleton. x-ray pictures were taken mostly with birds lying on their back.

5.4.2 Results

The findings in connection to each of the 29 eagles found after April 2007 are listed in **Table 7**. The majority of the x-ray pictures showed extensive skeletons damages, and 20 of the eagles were actually cut in two or more pieces. The findings of Follestad et al. (2007) were similar. Several of the eagles described as birds cut into two or more parts showed additional fractures. These fractures are not counted for as single fractures in the table.

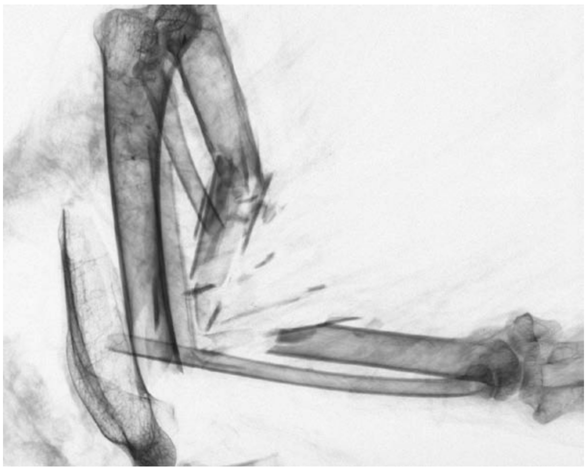
Table 7. *Post mortem findings of dead white-tailed eagles collected in connection with two wind-power plants in Central Norway. TN=wind turbine number. The age of each WTE specimen is given in calendar year (K) (see* ***Figure 42*** *for details on bone nomenclature).*

WTE number	Location	TN	Age	Post mortem findings
002	Hitra	23	5 cy	The remains of the eagle were quite putrid. The left wing was cut from the body *at articulatio humero-scapularis*. The joint between *humerus* and *radius/ulna* was distorted. Bones from both feet and pelvis (*os ilium* and *ischium*) were found separated from the rest of the body. The fractures of the feet (*tibiotarsus*) were very cleanly cut.
003	“	23	Ad.	Only bones and no soft tissue left, the eagle was almost overgrown with vegetation. The eagle had obviously died more than a year ago. Bones were found spread around the finding spot. Fractures were found in *os radius* and *ulna* of the left wing.
004	“	03	2 cy	The eagle was in a good state of nutrition. Right wing was cut off at the carpal joint. *Radius* and *ulna* have bone fractures all along the bones. Fragments of bones aligned like pearls on a necklace. Size of the fragments was 1-2 centimetres.
12A	Smøla	25	4 cy	Parts of a cadaverous eagle. The body was cut in a tilted transverse plane, midway across the body. Angle of impact from the front and sidelong towards *os sacrum*. Left wing showed fracture and dislocation of fragments in *radius* and *ulna*. Bones were splintered. Right wing showed multiple fractures in *humerus*. Multiple fractures and dislocations in the neck bones (*cervical vertebra*) especially near the head and breast aperture.
12B	“	25	4 cy	This was the cut off part from SE 12 A. Picture showed fracture of left *femur*, knuckle parts dislocated from each other. Small part of posterior part of the pelvis (*caudal vertebrae*) was present.
14	“	52	Ad	The eagle was in good state of nutrition. Found relatively fresh with no signs of cadaverosis. x-ray pictures show a fracture in the left clavicular bone. A wound, 7 centimetres in diameter, ventrally on the neck a little to the left of the midline. Extensive haemorrhages along the whole neck.
15AB	“	64	Ad	Relatively cadaverous body. Left wing without damage. Right wing had multiple fractures in *radius* and *ulna*, numerous pieces of bones with sharp edges. The neck was cut of (not present) at the breast aperture and at scull basis.
16BC	“	61	10 cy	The eagle was in good state of nutrition. The right wing was cut off from the body, found apart. The left wing showed fracture near *articulatio humero-scapularis*. Dislocation of knuckle fragments. Right leg showed numerous fractures near *articulatio femoro-tibiotarsus* (knee). The same findings could be seen in the left leg. The head was found separated from the body, as well as the neck bones (one piece).
17AB	“	37	Ad	Macerated eagle cut in two pieces. Cutting line was from front of *sternum* towards kidney region. No damage to the left wing. Right wing attached to the body has multiple fractures in both *humerus* and *radius/ulna*; see **Figure 41** A. Fractures in both legs, dislocated bones. *Os ischium* also fractured. Considerable external force applied to the body has been exerted. **Figure 41 B** show disintegrated bones.
18	“	38	4 cy	Eagle in good nutritional status. X-ray without remarks. The beak shows a fracture in the lower part of the beak. The injury prohibits normal use of the beak. The fracture must have been caused by an external force applied to the beak.
19	“	30	Ad	The carcass was quite putrefied. Scarce amount of soft tissue was present. Right wing shows fractures in *humerus* (upper arm) near the shoulder. Numerous loose fractured bones. Several dislocations of bones. Multiple fractures in *radius/ulna* of the left wing, distally of the carpal joint. Both legs cut off from the body, small part of femur left on the legs.
20	“	56	Ad	This eagle was found injured, and was later treated by a veterinar-

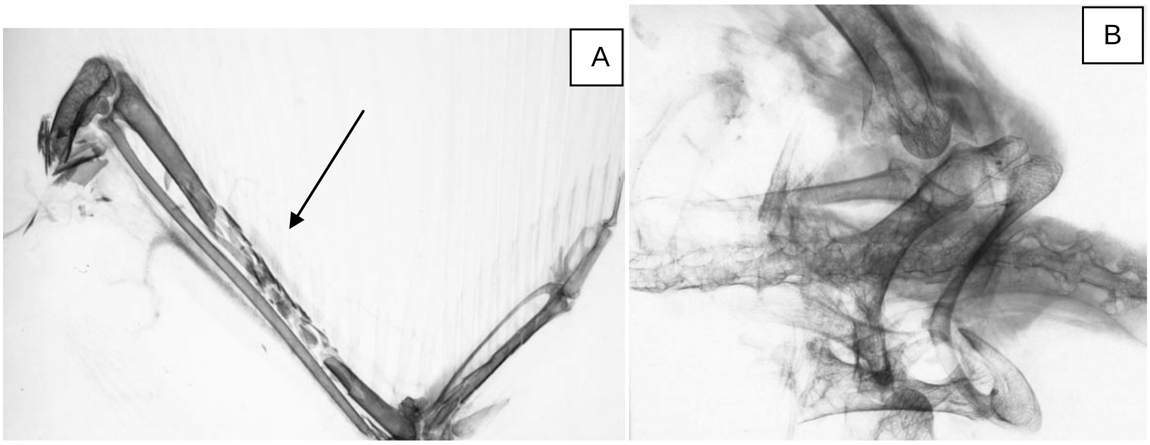
				ian for a fracture near metacarpus in the left wing. The eagle did not recover and was euthanized. One buckshot pellet found in breast muscle (x-ray diagnosis).
21	“	31	Ad	An eagle in good nutrition status. The left wing was found 75 meters away from the rest of the body. Cut off near the shoulder joint. No other findings.
22	“	09	3 cy	Eagle in good condition. Left wing cut off in the middle of *humerus*. No other findings.
23	“	68	5 cy	Almost no soft tissues left. Cadaverous.
24	“	24	4 cy	Fairly good condition. Distal part of right wing missing, cut off. Numerous fractures in *radius/ulna* distally on bones.
25	“	21	2 cy	Eagle in good condition. X-ray shows multiple fractures of the right *humerus* (upper arm) near shoulder joint.
26	“	20	2 cy	Eagle in good condition. X-ray shows multiple fractures of the right wing. The same picture present in the left wing. One buckshot also found in the left wing. Multiple fractures of the pelvis. The skull is crushed, *columna* near the skull separated from the rest of the neck.
27	“	06	1 cy	The body found cut in 2 pieces. Scavenged. Transversal cut in the middle of the body. Fractures of both legs in femur and tibia.
28	“	47	Ad	Female eagle in normal condition, fresh. Blood in beak and throat. Extravasations in skin on the scull and in periost of scull. Internal organs subject to bleeding, some blood in the body cavity. Multiple fractures in right wing, one in the middle of *os humerus* and two in ulna. Left wing without findings.
29	“	01	Ad	Eagle in good condition. Left wing cut off in the middle of *humerus.* No other findings.
30	”	01	4 cy+	Almost no soft tissues left. Cadaverous.
31	“	04	Ad	Fairly good condition. Distal part of right wing is missing, cut off. Numerous fractures in *radius/ulna* distally on bones.
32	“	59	3 cy	Eagle in good condition. X-ray shows multiple fractures of the right *humerus* (upper arm) near shoulder joint.
33	“	25	Ad	Eagle in good condition. X-ray shows multiple fractures of the right wing. The same picture present in the left wing. One buckshot found in the left wing. Multiple fractures of the pelvis. The skull is crushed*, columna* near the skull separated from the rest of the neck.
34	“	26	5 cy	The body found cut in 3 pieces. Scavenged. Transversal cut in the middle of the body. Fractures of both legs in *femur* and *tibia.*
35	“	42	2 cy	Eagle in good condition. Left wing (radius/ulna) cut off. Fracture of *humerus* in the right wing. Also multiple fractures in the reminders of left *ulna*.
36	“	24	6 cy	Eagle with no soft tissue left. The body cut in 2 pieces in the chest region, 10 cm from the breast aperture. A thin slice of skin keeps the body parts together. X-ray shows fracture in the middle of the right *tibia*.
37	“	53	3 cy	Cadaverous eagle. Left wing cut off in the *humero – ulnaris* joint. The wing found separately. Fracture of *tibia* right foot.
38	“	21	3 cy	Totally scavenged, no soft tissue left. Left wing cut off in the elbow joint (*articulatio humero – ulnaris*). The body cut in 2 pieces transversally across the chest right behind the scapular bones.

WTE 2

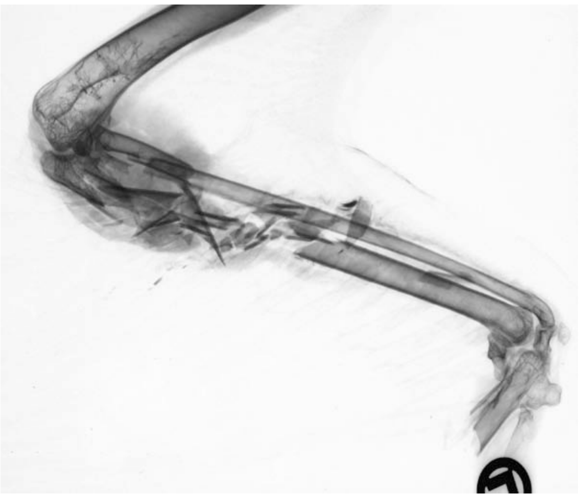
WTE 12



WTE 17 A+B



WTE 22



WTE 24

Figure 41. *X-ray images showing some typical injuries of white-tailed eagles killed by operating wind turbines in the Smøla and Hitra wind-power plants, Central Norway*.

Table 8. *Post mortem findings (fractures and their localization) in dead white-tailed eagles collected in connection to two wind-power plants in Central Norway*.

Bone	**Number of birds with fractures**
***Radius* and *ulna* (underarm)**	13
***Humerus* (upper arm)**	16
Phalanx	1
***Femur* (leg bone)**	12
***Tibiotarsus* (lower leg)**	13
Cranium	1
***Sternum* (breast bone)**	1
***Scapula* (shoulder)**	1
Cervical vertebra (neck)	3
Caudal vertebra (back of pelvis)	4
***Thorax* (breast)**	2
***Sternum* (front of breast)**	1
Clavicle (clavicular bone)	1
Carpal bone	3
***Rostrum* (beak)**	1

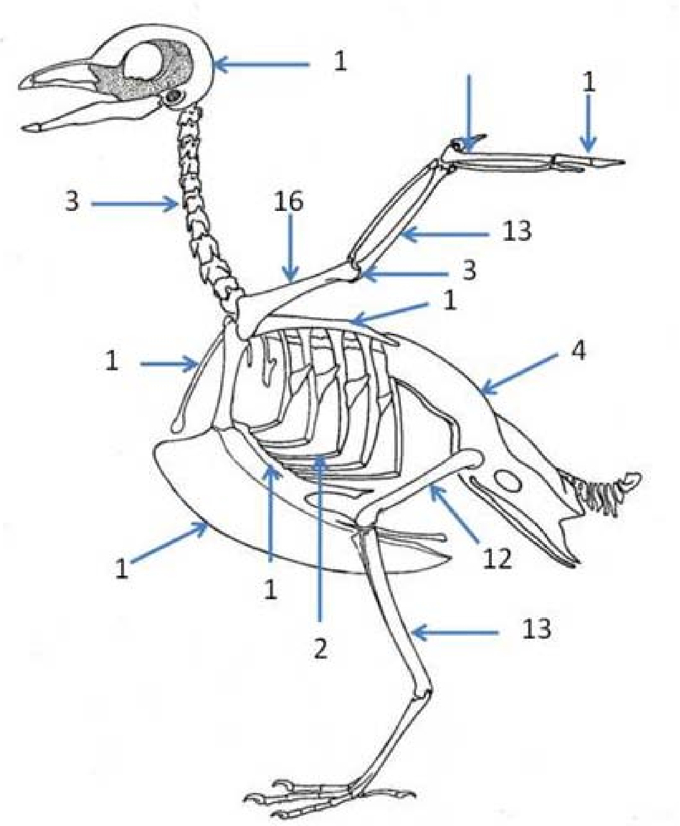


Figure 42. *Drawing of bird skeleton with total number of fractures (all eagles) indicated by arrows.*

5.4.3 Discussion and conclusion

All eagles in this study were found close to wind turbines. The x-ray pictures show a broad spectre of fractures (**Figure 41**). Several birds had one wing cut off, but the majority had multiple fractures related to different parts of their bodies. In a study on birds colliding with aeroplanes (Lyne et al. 1998), the birds had a tendency to get injured in their ventral surface, suggesting that they tried to avoid the aeroplane in the last minute before impact. The findings in our survey do not show a similar picture; lesions are complex and spread more evenly on the skeletons. The fracture pattern actually is more like those seen on animals involved in traffic accidents. Such devastating and mortal power applied to the bodies induces a quick death as damage was found on all body parts (**Table 7**).

It is not uncommon to find dead birds with one or more fractures to the skeleton, but not as extensive as the findings in this survey. Birds are known to collide with objects or structures that are artificial to them, e.g. power lines, windows etc. (Bevanger 1994). In this study the picture is strikingly different. The number of fractures in a considerable number of the specimen are of a much higher number than found in bird carcasses obtained from areas without wind turbines. A single finding of one dead eagle is not always suitable for determining the cause of death. However, 39 WTEs with a relatively high number of skeleton fractures cannot be explained by other causes than heavy and lethal collisions with the spinning turbine rotor blades. A great number of bones had many splintering fractures with sharp edges. It is not possible to point out other reasons than wind turbine blades for this than excessive and sudden application of force to the bodies.

A majority of the specimen were quite putrid and not very well suited for autopsy. However, despite the carcass condition, x-rays reveal a number of severe fractures to the skeletons. Our conclusion is that the fractures were established by application of considerable external force to the bodies. The x-ray pictures show a pattern of violent impacts inflicting massive damage to the skeleton, although some had minor damages. Still, a minor damage can lead to death, if the bird is not able to fly or feed normally. In this context, one can speculate whether there are some additional birds that initially survive a strike, and subsequently manage to move themselves out of the searched area to escape detection.

5.5 White-tailed eagle behaviour inside and outside the wind-power plant area

Subproject responsibility: Pernille Lund Hoel, Kjetil Bevanger, Hans Chr. Pedersen, Eivin Røskaft, Bård Stokke

Objectives: Observation of WTE behaviour inside the wind-power plant area and in an adjacent control area, to collect data on possible behavioural differences as a response to the wind-power plant.

5.5.1 Methods

To investigate behavioural differences related to the distance from the turbines, data on flight activity (moving flight, social behaviour and soaring) and flight height (below, in and above the rotor zone) were collected at 12 vantage points, 6 from inside the SWPP area and 6 from control areas close to the SWPP. In order to investigate possible differences inside SWPP versus the control area, observations from the 12 vantage points have been separated into two groups (6 vantage points in each) in some of the analysis and named control area (CA) and the SWPP.

First, possible explanatory variables that could account for variation in general activity were tested. Second, variables that could account for variation in flight activity and flight height were tested, and third variables that could explain differences between the flight activities and flight heights were testeded.

Any variation in the two response variables (flight activity and flight height) could possibly be explained by several different explanatory variables. In order to test which variables that influence on variation in the response variables, data were collected on distance to nearest turbine, distance to nearest active nest, number of individuals observed together, date, time of day, weather (precipitation, temperature and wind speed), and age of individuals. Data collected from 144 observation hours, during mid-March to the end of May 2008, were analyzed using ANOVA, Chi-square tests and multinomial logistic regression.

5.5.2 Results

The only explanatory variables that showed a statistically significant effect on the general activity were week, number and distance to nearest, active nest. The results showed a statistically significant difference in activity among the weeks. The general activity peaked in April (week 15 and 17) which is the first part of the breeding period for the WTE (**Figure A**). Moreover, more activity was observed at distance 0-500 m than further away from the nearest active nest. There was more activity at 0-500 m than further away from the nest, which probably could be due to defending territories and delivering food to the nest (Dementavicius & Treinys 2009). Neither distance to nearest turbine, nor the locations seem to have any effect on the general activity.

The results showed, furthermore, a statistically significant difference in age distribution between the two locations, with a higher percentage of adults in the CA and a higher percentage of subadults in the SWPP area (**Figure B**). There was also a statistically significant difference between the age categories in the different observation weeks with more adults than subadults represented throughout the whole study period.

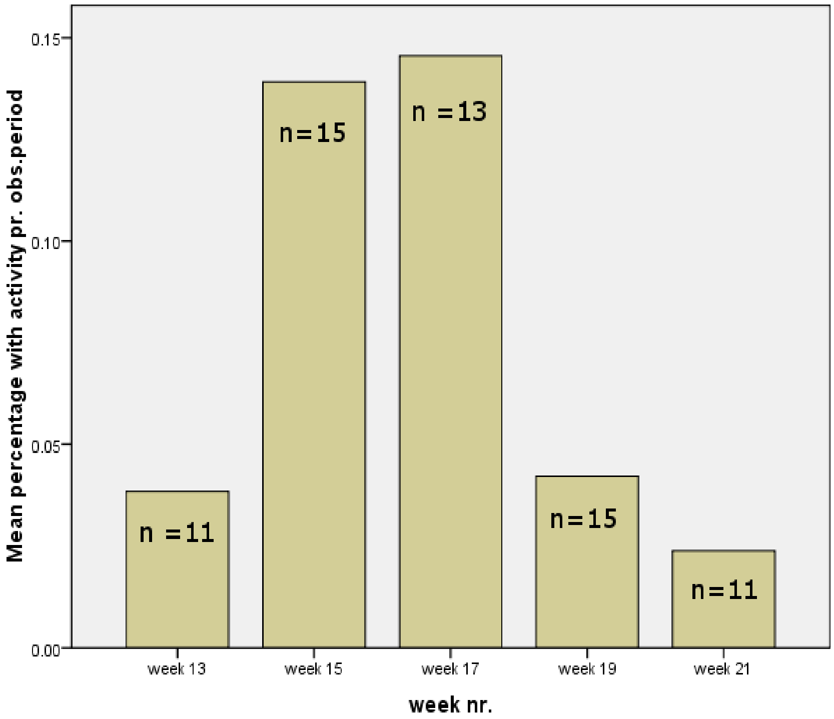


Figure A. *Observed flight activity (%) of WTE of total observation time pr. observation week. N=number of two-hour observation periods.*

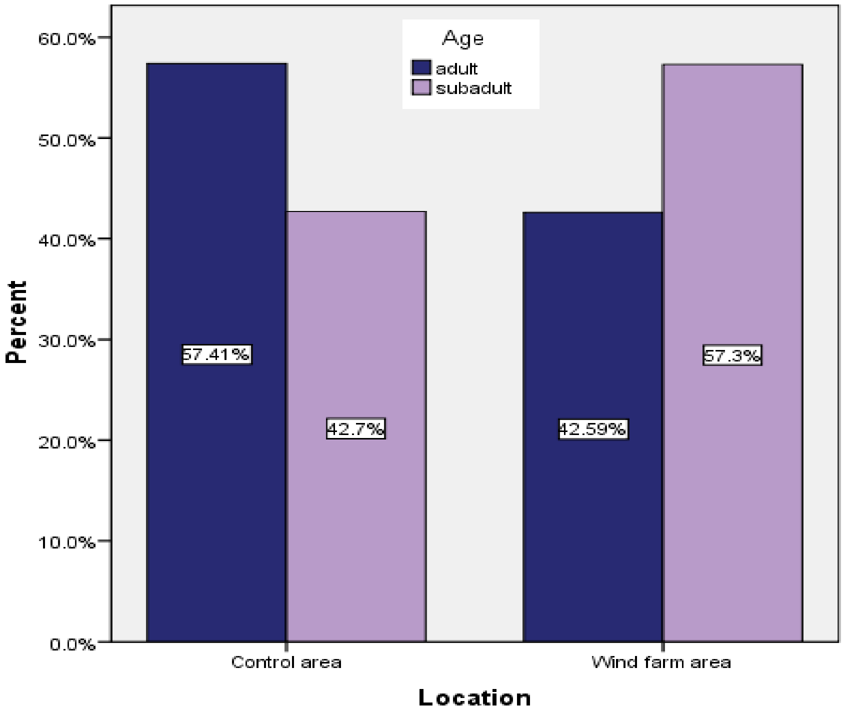


Figure B. *Age distribution (%) of WTE in the control area and the wind-power plant area ($N_{CAadult}$=182, $N_{CASubadult}$=79, $N_{WPAadult}$=135, $N_{WPAsubadult}$=106).*

Regarding flight activity, the results from the multinomial regression analyses showed a statistically significant difference between moving flight and soaring in number of individuals observed together, with more individuals observed together in moving flight than in soaring (**Figure C**). This could possibly be caused by pairs of individuals performing moving flight when moving back and forth between territories and feeding areas (Dementavicius & Treinys 2009).

Furthermore, there was a statistically significant difference between social behaviour and the two other activity categories in number of individuals observed together, with more individuals observed together in social behaviour than in moving flight and soaring. There was also a significant difference between social behaviour and the other two activities related to age, with more adults than subadults in social behaviour than in moving flight and soaring. Since adults are reproductively active in contrast to subadults, and therefore more likely to participate in social behaviour in order to increase their fitness, this result is as expected.

Soaring was statistically significant different from the two other activity categories in relation to flight height, with soaring only occurring in – and above the rotor height, while moving flight and social behaviour occurred in all three flight-height categories. One reason for this is that the WTE can climb in altitude during sustained soaring and in this way gain high altitudes.

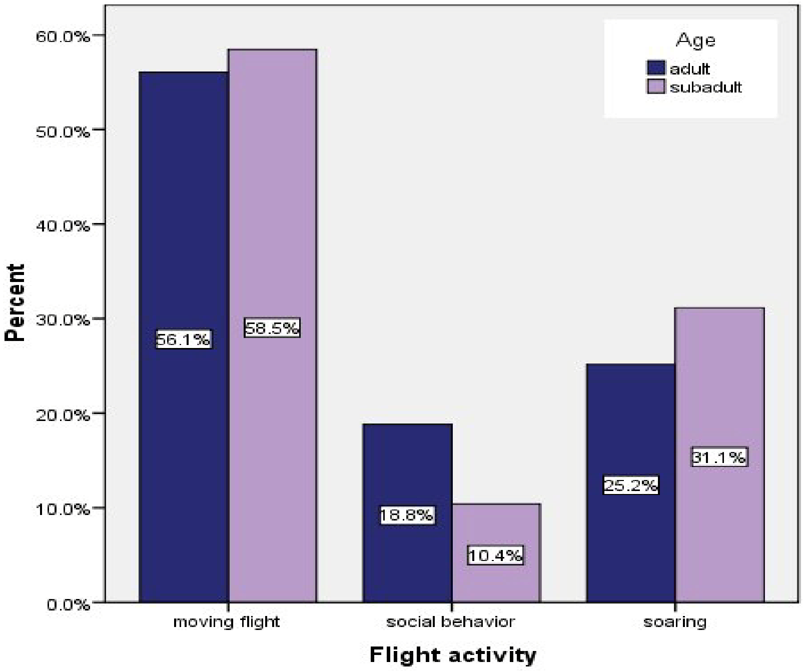


Figure C. *Observed age distribution (%) of WTE in the different flight activity categories.*

Furthermore, a statistically significant difference in age distribution between the two locations appeared, with a higher percentage of adults in the CA and a higher percentage of subadults in the SWWP area. This could indicate that the adults are either behavioural displaced away from the SWPP, or that there are a higher percentage of adults than subadults killed inside the SWPP area. One possible reason for this difference could be connected to social behaviour. A much higher percentage of adults than subadults are involved with this type of behaviour, and this can possible impose a greater risk due to decreased awareness of the surroundings, or/and the fact that there are more activity in the air during the period were social behaviour are most important for pair-bounding, as also the analyses of the effect of week number on the general activity suggest.

Because of low sample sizes due to low breeding densities, raptors are among the most difficult group of birds to demonstrate effects of disturbance, thus more long-term studies are needed. In order to test the assumption about social behaviour imposing greater risk to collision than the other flight activities, it is therefore necessary to conduct more long-term studies. More studies will also give larger sample sizes, which can give the opportunity to distinguish between more types of flight behaviour (e.g. more types of social behaviour).

Other studies (Henderson et al. 1996) indicate that moving flight could impose a greater risk than the flight activities because adults are flying more frequently under or between man-made structures in order to reduce their journey time when rising young. This study show that moving flight is the activity that is most observed both inside the SWPP and the CA, and in both age categories. One alternative explanation for the high amount of adults found killed could therefore be that moving flight in relation to parental care could impose a higher risk for the adults than the subadults.

5.5.3 Conclusion

The overall conclusion is that white-tailed eagles on Smøla do not seem to have any behavioral responses to the wind-power plant construction. This may explain the number of killed individuals recorded in the wind-power plant. The behavioural differences between adults and subadults found, increase our understanding of the age difference among the individuals found killed inside the wind-power plant area. A higher number of adults than subadults found killed can be due to behavioural differences, like more time spent on social behaviour and flying back and forth between nests and feeding areas. Furthermore, if such behaviour is increasing the risk of collisions for adult individuals, this can contribute to explain the higher number of recorded subadults inside the wind power plan area found in this study. This should be carefully considered when looking at the possible long-term effects of the wind-power plant on the white-tailed eagle population on Smøla. Assuming that the overall conclusion is correct, it clearly imposes limits to the possibilities for mitigating measures to decrease the white-tailed eagle collision hazard. The results underline the importance of conducting thorough pre-construction studies to identify wind-power plant siting with low densities of species vulnerable to collision. A more accurate prediction of high-hazard collision periods based on environmental variables like air temperature, wind and precipitation triggering high flight activity in March-May, would make it possible to advise the wind-power plant operator when to close down the wind-power plant during high-hazard conditions to reduce eagle mortality.

6 Bird radar

Subproject responsibility: Roel May, Yngve Steinheim

Objectives: To develop radar as a tool for learning more about the effects of single wind turbines and wind-power plants on birds.

The study of behavioural responses of birds to man-made structures like the wind-power plant at Smøla, requires ways to observe and document the movement of birds in the area of interest. Human visual observation remain an indispensable prerequisite and a key method, but a dedicated radar system is a powerful instrument which greatly extends the observation capability, both in terms of observation period, and the size of the surveillance area. E.g. the radar can be set to cover the relatively large area of wind-power plant, and operated 24 hours a day all year round at all types of weather conditions, which is a task impossible to achieve with the use of human observers alone. At the same time the radar offers means for continuously recording of the radar picture which provides documentation of the activities in the surveillance area. However, the use of radar for this purpose has site- and system-specific limitations that are important to be aware of when the data output is evaluated.

An important task in the project has been to start using radar as an instrument to monitor and record bird behaviour in the vicinity of large wind turbines. To our knowledge, it is the first time radar has been deployed for this kind of research in Norway. Important objectives of this work package have therefore been to experiment and develop the necessary methods, and gain general experience using radar as a research instrument. The following paragraphs give an overview over the activities performed on this subject.

6.1 Radar installation

At the onset of the project it was decided at the user meeting in 2006 that NINA, together with SINTEF, would develop an outline pilot project to obtain more knowledge of possible methods of reducing the danger of WTEs being killed by wind turbines. The pilot project was completed in the spring of 2007; SINTEF concluded that given time and economic constraints, it would be most realistic to invest in a commercially available mobile avian radar system specially designed for the purpose. It was further decided that the costs of radar and other technical equipment would be financed by Statkraft. This part of the work culminated in late October with the signing of a contract with DeTect for the purchase of a mobile avian radar system (Merlin Avian Radar System, Model XS2530e); delivered trailer-mounted to enable easy relocation to any desired location. The radar was shipped from Florida in early February and arrived at NINA Headquarters in Trondheim in late evening March 7th 2008. Andreas Smith from DeTect had arrived in advance of delivery to tailor the radar computer equipment for Norwegian conditions. On delivery and start up he gave operation and maintenance instructions to the radar operators. A permit to operate the system within the SWPP area has been obtained from the Norwegian Post and Telecommunications Authority.

From the beginning of 2008, Roel May from NINA started a postdoc position focusing among others on developing new methodologies for the assessment of avian collision risks (i.e. on-site mobile radar technology, trained dog searches, video-based detection systems). He has the specific responsibility for the avian radar. The radar was pulled with a SUV to Smøla on March 8th 2008 and prepared for operational use. It became operational within a few days and week 11 was used to look for optimal locations within the wind-power plant area. After much trial and error the most suitable location to place the radar was in the centre of the wind-power plant area (see **Figure 43**). From here, the horizontal radar covers the entire wind-power plant including its direct surroundings. The vertical radar covers a 20 degrees sector which was either directed due north, southwest or east.

Since April 3rd 2008 the radar has started recording bird activity continuously from this location. The radar system gathers data using horizontal S-band radar and vertical X-band radar. Within the trailer the radar images are automatically processed and detections are stored in MS Access databases, which are downloaded automatically once a day to NINA headquarters in Trondheim through a wireless broadband connection. The radar system detects and tracks birds (‘targets’) of various sizes on the horizontal plane within a circular area with a radius of 3.7 km (2 nautical miles). In addition flight altitudes up to 5000 m are recorded within a 20 degrees sector with a width of approximately 300 m and a range of 2.8 km (1.5 nautical miles). Because the system is built on top of a trailer, it can be placed practically everywhere on level ground. It may be powered either by generator or commercial power; at Smøla it has been connected to one of the wind turbines since the end of August 2008. Prior to this, the radar was powered by the generator. During spring 2008 we experienced several practical problems with the radar due to temporary generator failures, a radar hardware fault and software related issues; which were solved rapidly.

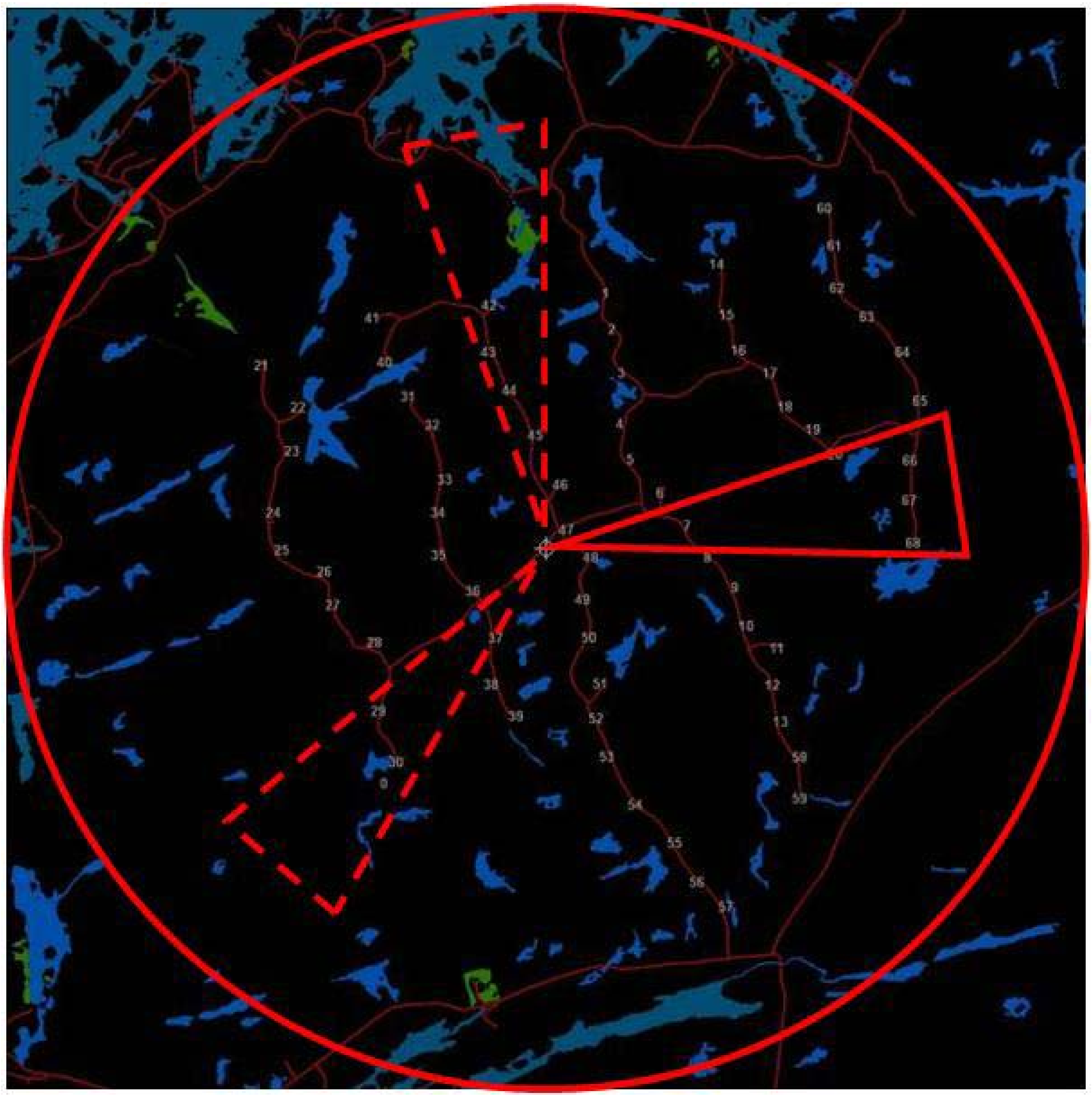


Figure 43. *Location of the MERLIN Avian Radar System within the Smøla Wind-power plant. The circular area shows the coverage with the horizontal radar; the three strips indicate the different directions and coverage employed for the vertical radar*.

6.2 Radar data collection management

The main focus in 2009 and 2010 have been development of GIS-tools to learn more about the radar range and scanning accuracy (see paragraph 6.8), development of database routines (see also paragraph 6.7) to optimize radar data (including false alarms filtering and categorization of bird tracks using data-mining techniques), and experimental tests of the radar performance with respect to accuracy in detecting and following birds using model aircrafts and ground-truthing (identify bird species spotted by the radar by field observations). Methodological challenges of the radar system are to which extent the tracking-algorithm is able to record bird flights, verification of recorded radar tracks to species and characterisation of species-specific track-characteristics to enable extrapolation to the entire database.

6.3 Ground-truthing and track database

Since the start of the project 1,764 bird track-segments have been ground-truthed (**Figure 44**). A ground-truth protocol has been established to enable a representative collection of data. Using a rugged laptop, which is remotely connected to the radar system through the GSM-network, ground-truth data can be collected at any given vantage point (i.e. every wind turbine) within the range of the radar. This ensures that data is collected from different sites, in different environments and at different distances from the radar. Based on this database, the radar-detection capability and species-specific parameters (e.g. size, shape, reflectability, speed, and movement pattern) can be identified, which characterize the species within the radar system. This “radar-characterisation” of different bird species enables extrapolation to radar targets/tracks with a similar signature.

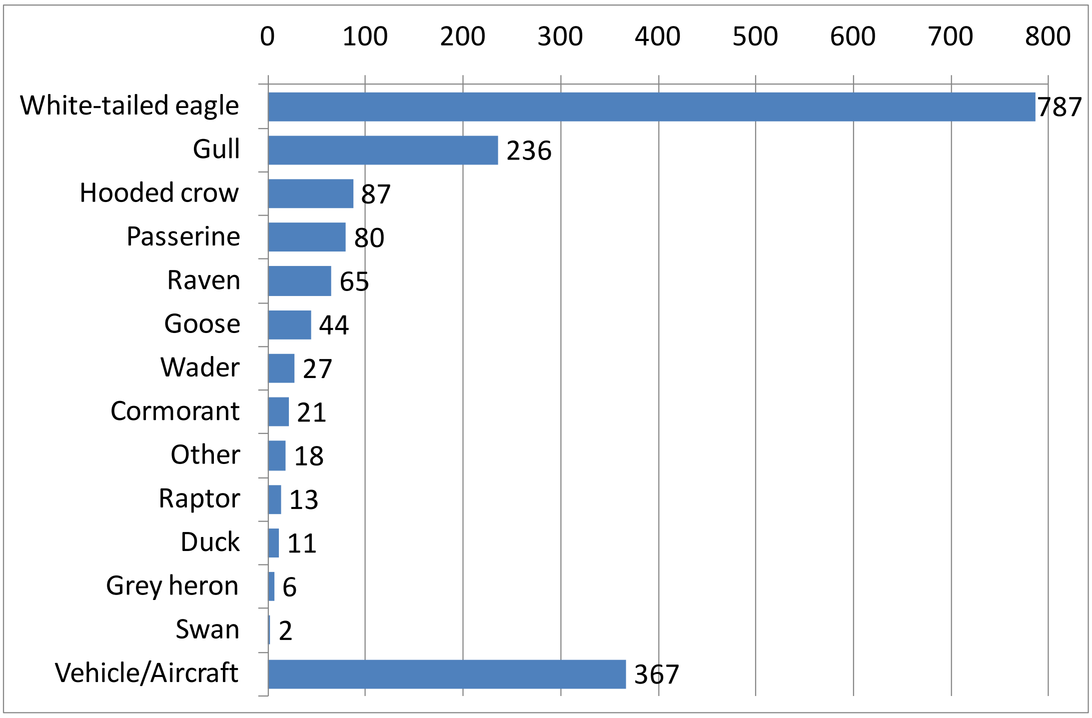


Figure 44. *Number of ground-truthed radar tracks for each given bird species (group) during the period 02.04.2008 – 28.06.2010 on the horizontal S-band radar. The many vehicles/aircraft ground-truthed reflect the testing activity with the model airplane.*

The development of database routines to optimize radar data has resulted in a framework which employs data-mining techniques (in order to filter out false alarms and classify bird tracks to species (group)). The framework builds on a random selection of over 800,000 tracks from the entire radar database. For each track a summary is calculated giving the average and variation in track length, speed and acceleration, target size and shape, reflectivity, tortuousity, percentage within clutter areas (i.e. areas where false alarms may be expected due to turbine interference; see also paragraph 2.8) and weather (precipitation and wind speed) (i.e. a measure for the 'twistedness' of the track). Microsoft SQL Server Data Mining Clustering technique is used to identify the clusters found within the multidimensional space of this track-data set (see **Figure 45** for an example). The signatures of the derived clusters are thereafter identified, and analysed in a semi-quantitative manner using qualifier (e.g. long tracks are likely to be birds) and disqualifier (e.g. large within-track variation in the parameters; high percentage of tracks within turbine interference areas) criteria. Thereafter the ground-truth data is used to verify in which clusters these tracks of known birds (and species) fall; other (unknown) tracks within the same cluster, with a similar signature, thereby should also be to birds. Using a decision tree approach, the signature of birds can be derived and extrapolated to all tracks in the database. Thereafter, with a decision tree white-tailed eagles can be recognized using the ground-truthed data.

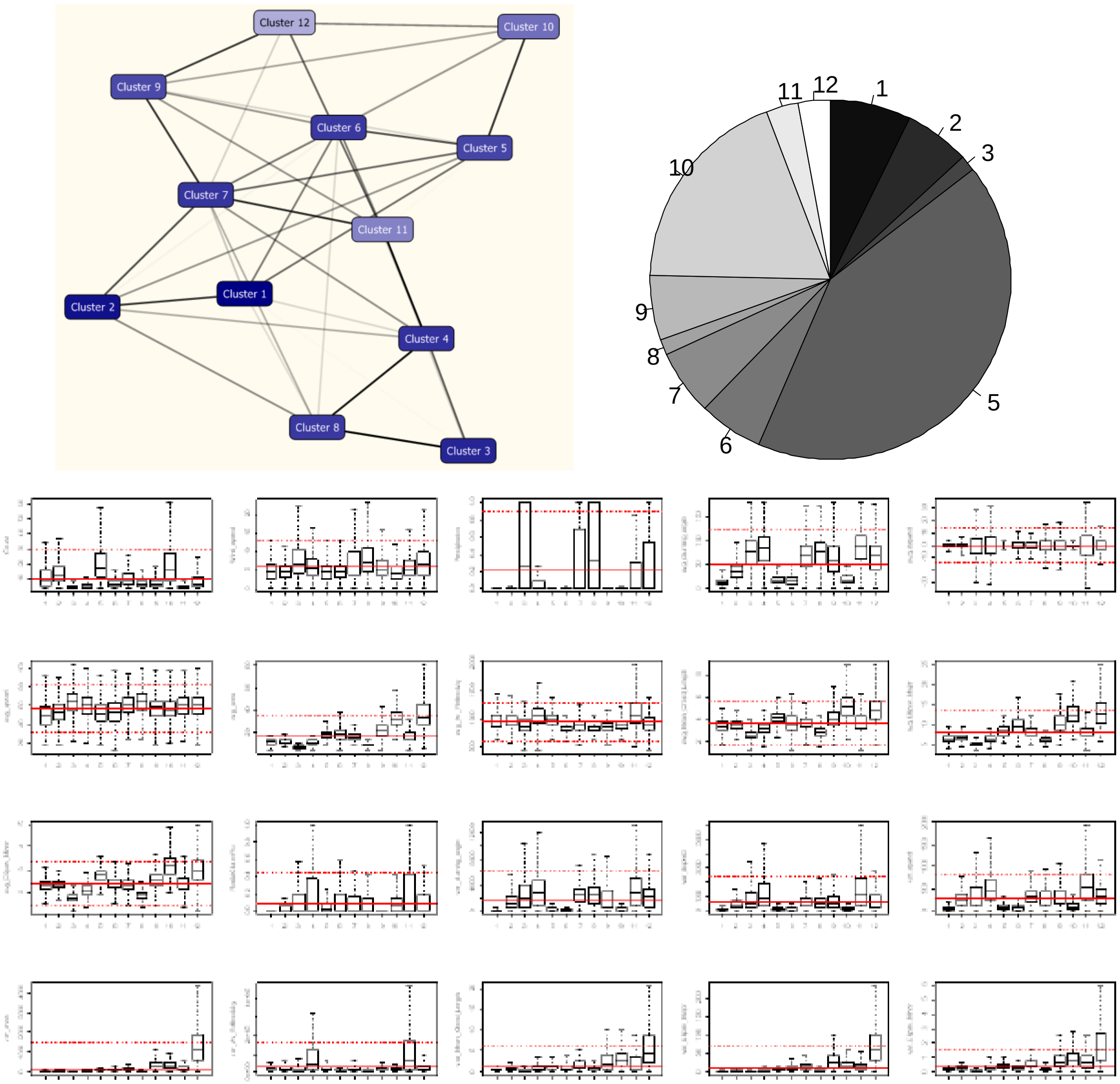


Figure 45. *Exemplary results from the Microsoft SQL Server Data Mining Clustering technique based on a test database. The pie chart gives the distribution of the ground-truth tracks over the*

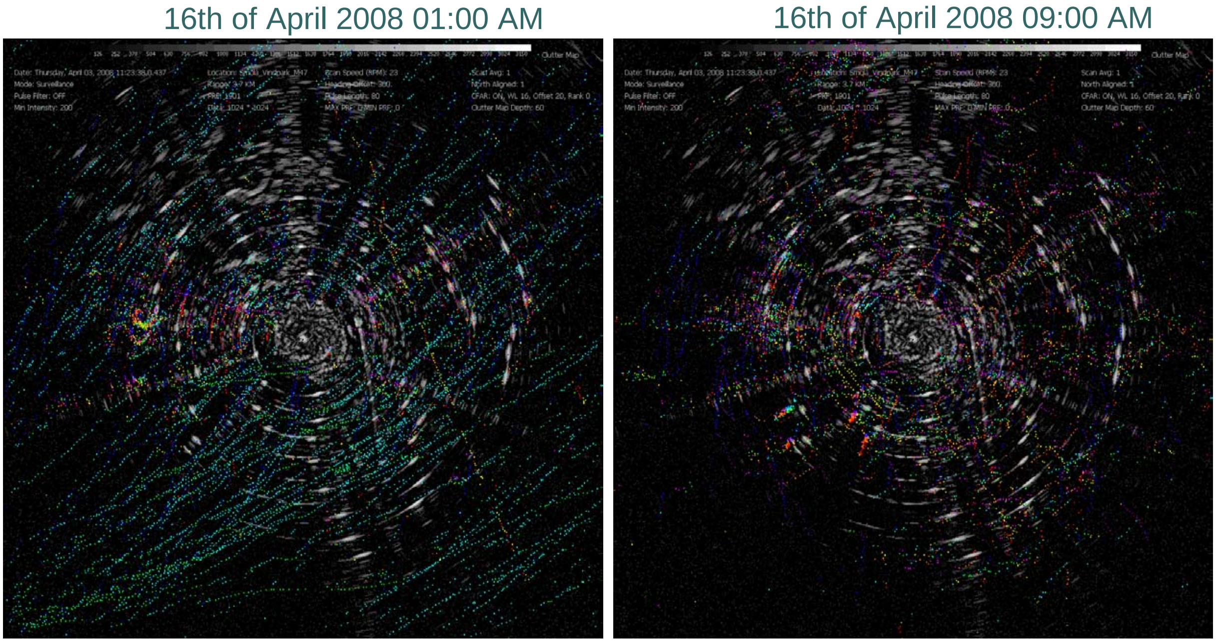
different identified clusters. Approximately 67% of all ground-truthed tracks fall within clusters 5 and 10, making these likely bird-clusters. The 20 box plots show the signatures of the different clusters. In this example, clusters 1, 2, 5, 6, 7, 10 and possibly 9 represent birds. Clusters 3 and 8 resemble mostly rain; clusters 4 and 11 seem to be the result of interference; while cluster 12 represents outliers.

6.4 Radar-based analyses

The aim is to finalize the methodological aspects of the radar operation and database optimization by the end of 2010. Thereafter analyses of the radar data will receive the main focus. The analyses will focus on the following topics:

- Avoidance of wind turbines in birds (response distances, avoidance probabilities)
- Temporal and spatial patterns in bird activity and weather correlates

The first preliminary results from the radar data clearly show the spring migration activity, which is at its heaviest in April (**Figure 46**). Migration activity was highest during the night; whereas daytime activity shows a pattern more characteristic to resident bird activity. The migration was directional towards north to northeast and mainly happened at higher altitudes (i.e. high over the SWPP); although some avoidance of the wind-power plant has been recorded.


16th of April 2008 01:00 AM

16th of April 2008 09:00 AM

Figure 46. *Example of bird activity on the 16th of April 2008; migration during the night and local activity during the day*.

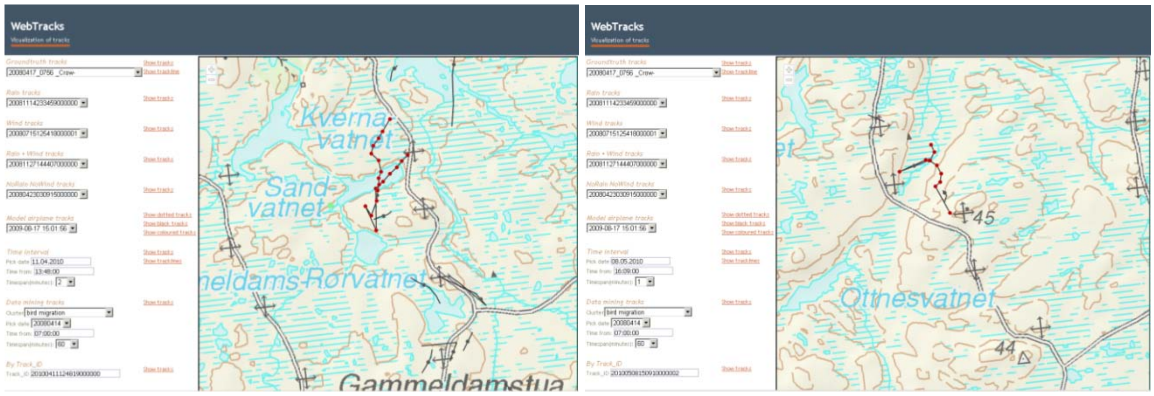


Figure 47. *White-tailed eagle collisions observed on April 11th 2010 (left) and May 8th 2010 (right). The collisions have been recorded by the avian radar, and occurred exactly at: 13:49:18 and 16:09:37 local time, respectively.*

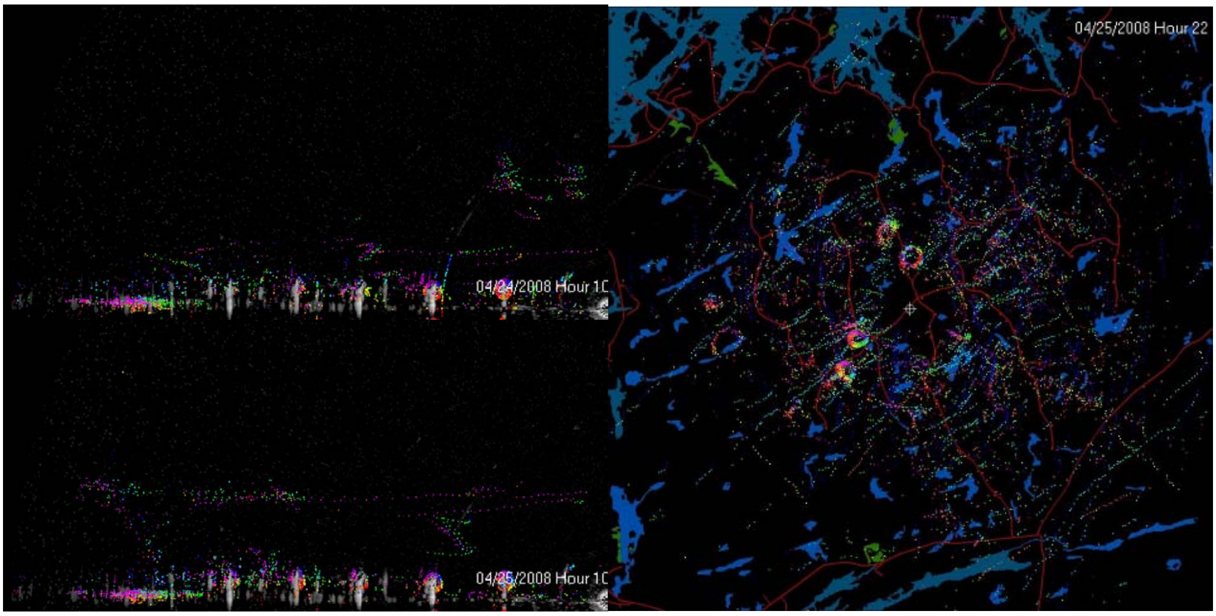


Figure 48. *Example of bird activity: To the left white-tailed eagle circling; to the right so-called "bird circles" of an unknown bird species.*

A central component within the radar studies is the verification whether WTEs that have been found killed by a wind turbine have actually been tracked by the radar. Although these analyses can only be done properly when the radar data optimization is in order; some clear examples have been recorded (**Figure 47**).

The fine-scale recording of avian movements of the radar (i.e. one tracking point every third second) enable more detailed analyses in the further work of bird movement and behavioural patterns. Specific WTE behaviour, such as thermal circling (cf. **Figure 48** – left-hand panel), can easily be distinguished. Also other, as yet unexplained, circular phenomena have been recorded during spring (cf. **Figure 48** – right-hand panel). As yet we do not know what causes these circles, which were performed at one specific altitude below or at rotor-swept height especially at night (21:00-03:00) towards the end of April.

Investigation of the spatial requirements (i.e. habitat selection, flying patterns) of WTE in the coming years will enhance our understanding of their spatial response to wind turbines at different scales. Flying behaviour will be assessed using both GPS radio telemetry data (see paragraph 6.4.1) and radar flight tracks. The spatial responses of WTEs to wind turbines at different spatial scales will simultaneously form important bird-related information for the development of the collision risk models. The purpose of constructing collision risk models is to identify which factors contribute to an increased risk of collision between birds and wind turbines.

Preliminary results from the ground-truthed white-tailed eagle tracks indicate a higher utilization of the western half of the SWPP (**Figure 49**). From this map we assessed any avoidance from wind turbines, by relating utilization with distance to nearest wind turbine. On average the distance between neighbouring turbines within the same row is approximately 250-350 m, while the distance between turbine rows is 500-800 m. Here we only used those parts of the data where the distance to the closest turbine (D) was $40 < D < 500$ m. The modelling was based on data from the horizontal radar only, and did not include data on flight altitudes. The model controlled for increased probability for tracks being above the rotor-swept zone over range, by weighing each track by the proportion of the radar beam below the rotor-swept zone (i.e. decreasing proportion over range). This was done to avoid spurious results due to the effect of deteriorating detection over range (see paragraph 6.5.5); which was also directly controlled for by including a non-linear effect over range. The results from a generalized additive mixed model, also taking into account spatial autocorrelation, showed a slight decrease in utilization closer to the wind turbines (**Figure 51**). The result shows a clear decline in utilization over range around 2000 m; which lies near the expected detection range for WTEs (see also paragraph 6.5.5). The lower utilization at close range to the radar is due to interference (i.e. the radar does not see any targets at close vicinity of the radar; see also the central part of **Figure 50**). Given the slight decrease in utilization nearer the turbines, we feel this effect is likely due to avoidance of the actual physical structures.

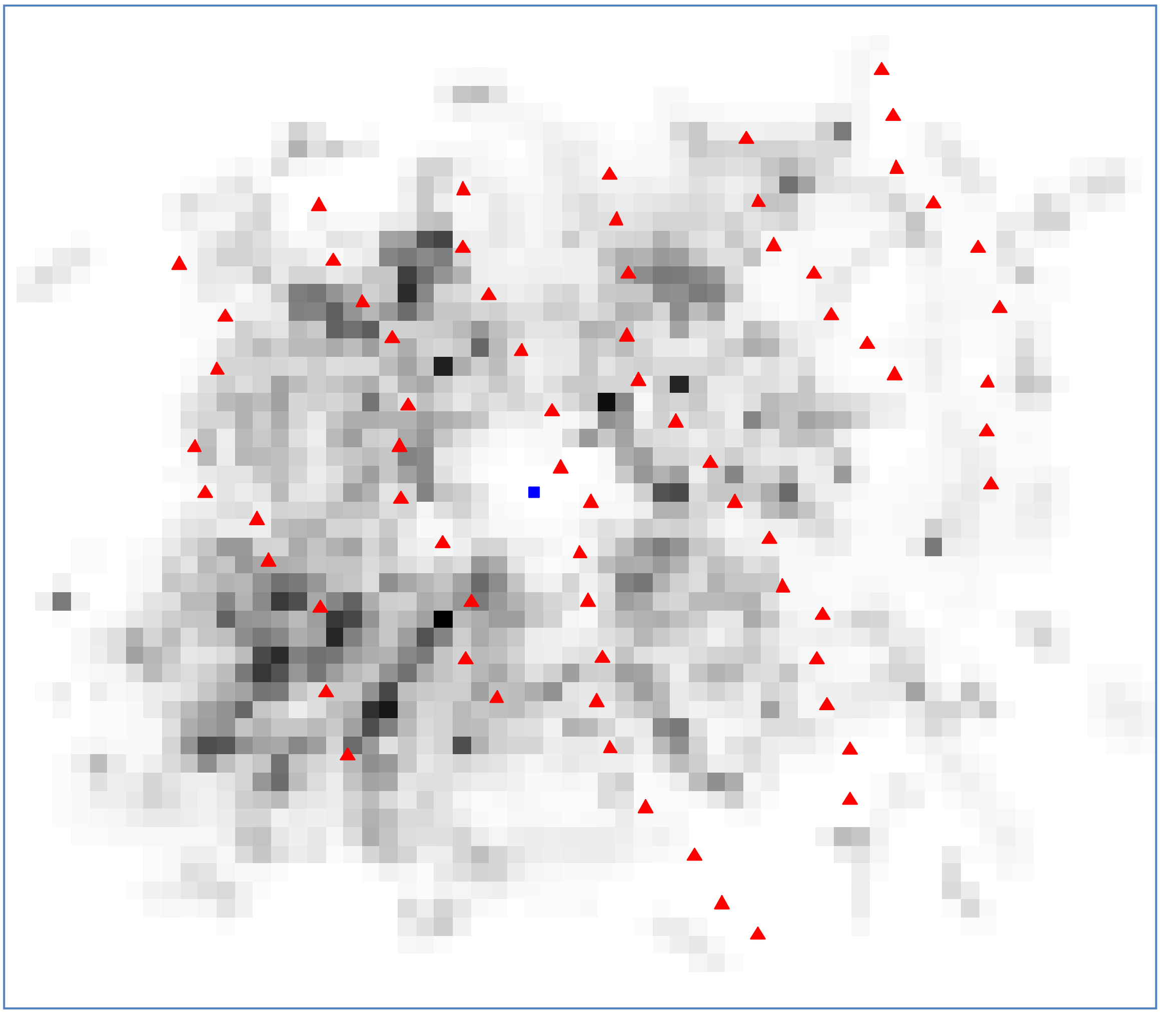


Figure 50. *Utilization distribution of 432 ground-truthed white-tailed eagle tracks. Darker (100x100 m) squares indicate a higher density of tracks. No or less tracks can be seen close to the radar (blue square) and near the wind turbines (red triangles) due to interference.*

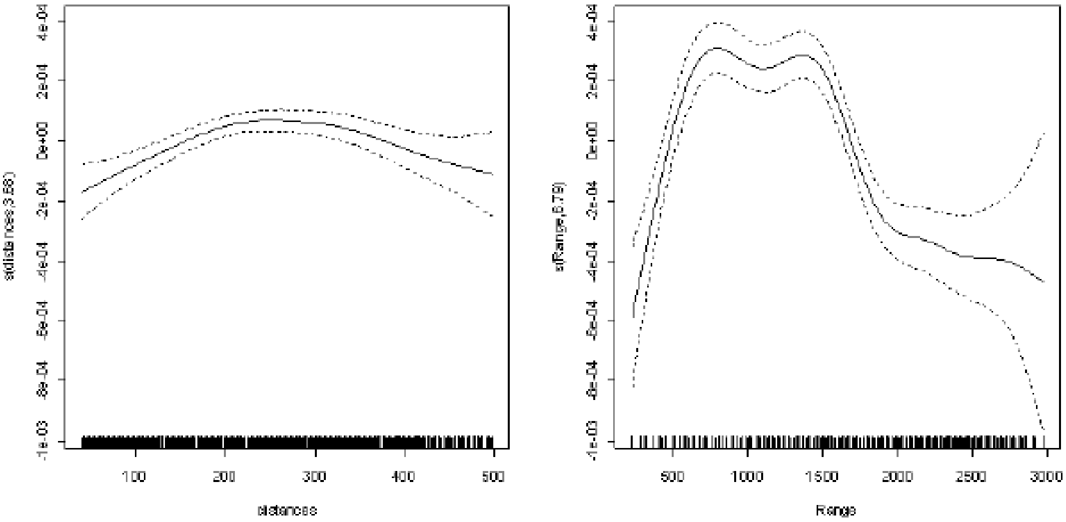


Figure 51. *Non-linear relationship between white-tailed eagle utilization density and distance to nearest wind turbine (left); while controlling for deteriorating detection over radar range (right).*

6.5 Radar performance tests

6.5.1 Background and objectives

A theoretical assessment of the radar system performance was carried out before installation; however the actual performance in a particular site depends heavily on the specific environment at that particular location. The specific radar location within the SWPP represents some extraordinary challenges for the radar. In addition to ground clutter, the echo from the large wind turbine structures causes heavy interference which will mask the detection of smaller targets like birds if they happen to be in the same radar resolution cell. We have also experienced significant ground clutter behind the turbines, caused by energy being reflected off the turbine blades and the nacelle down to the ground behind the wind turbine and taking the same way back to the radar, creating stripes of ground clutter behind each turbine (see also paragraph 6.8). To investigate MERLIN performance at its current location within the SWPP, field trials with dedicated controlled targets have been performed. This effort was meant to serve several purposes:

- Optimization of radar settings. The MERLIN processing functions have a set of parameters which can be adjusted to each operational task and environment. The flight tests provide data which helps in optimizing these processing parameters.
- Provide the research team with detailed information on actual radar performance both to ensure proper set-up of the various experiments and field surveys, and as an important prerequisite to take into consideration when the bird flight data collected by the radar is analyzed later.
- Provide a radar performance baseline for future quality control, e.g. before particular important recording periods, to ensure that the original performance is maintained.

The most important performance system capabilities to verify are:

- *Detection in the clear.* I.e. the maximum detection range for a given size target only limited by system noise. This is the most basic and important performance capability of any radar system.
- *Target accuracy*. The accuracy of the reported target position when it is recorded depend on two components: one random error that is due to statistical variation in receiver noise and influenced by radar parameters like beam widths and the receiver noise factor, and one systematic error due to misalignment of the radar to the surrounding terrain, usually both in bearing and range. The random component can only be measured and used as an important prerequisite when data is analyzed. The systematic error can be measured and adjusted for so that it is removed in subsequent data recordings.
- *Target resolution*. Quantification of targets requires knowledge of the resolution capability of the radar, i.e. the minimum distance between two targets with which the radar will still report two separate targets instead of one larger merged target.
- *Detection over ground clutter areas*. A percentage of the surveillance (horizontal) radar coverage on Smøla is influenced by unwanted echoes (clutter) from the wind turbines and the ground (see also paragraph 6.8). This clutter will reduce the detection capability of birds in the affected areas; it is however important to find out to which extent.

6.5.2 Test method

The main approach taken to radar-performance testing has been to use a controlled test target in live flight tests in the actual operational environment inside the SWPP area. To provide a realistic view on the actual performance with real targets, the test targets should correspond to the actual targets to be tracked as closely as possible in terms of radar cross section and flight behaviour.

The first trials were made using a small conducting sphere as the test target. To move the test target around within the radar coverage, the sphere was towed behind a remotely controlled model aircraft. The advantage of using a sphere as the test target is that its size, i.e. Radar Cross Section

(RCS), is accurately known for any given radar wavelength, and related to its radius with a simple formula. This would make it possible to test the radar with different size-test targets simply by using different size spheres. Unfortunately the actual radar resolution, given by the extraction algorithms in the radar processor, was not narrow enough to allow for proper resolution with the towing aircraft at practical line lengths. In addition, towing a sphere behind a model aircraft poses a real challenge to the remote-controlling pilot on the ground, and places severe restrictions on the freedom to manoeuvre and thus limiting the flight patterns possible to perform. Therefore this method had to be abandoned. Instead the model aircraft itself has been used as the test target.

A model aircraft has a relatively short visual control range and usually has to be kept within 500 m from the controlling pilot on the ground. To be able to conduct long-range radar tests, NINA has rigged a model aircraft with video camera and video transmitter (**Figure 52**). This enables flying beyond visual sight range. In august 2009 ranges in excess of 2 km from the pilot position where obtained. The aircraft is controlled on the 35 mHz band, and the onboard video transmitter is transmitting on the 2,4GHz band. The aircraft is controlled using video goggles, also known as First Person View (FPV) flying.

Figure 52. *Model aircraft with video camera and transmitter used for radar-performance testing.* Photo: Pål Kvaløy.

This technique provided the freedom to design and perform virtually any test-flight pattern within the SWPP area. In addition, an on-board GPS logger accurately recorded the aircraft position during the flight. The recorded GPS data was later compared to the target position reported by the radar for the same flight, and served as an aid to do both accuracy and detection analysis.

To be able to find the detection performance for a given bird size, the model aircraft RCS had to be compared to the RCS data of the species in question, and the detection range found for the aircraft was therefore used to calculate the corresponding theoretical detection range for the given bird RCS. Simple models for the RCS of different bird species can be found in the literature, and the necessary extrapolation of detection range is a trivial task using the radar equation, but it requires that the size of the test target is known, and preferably that it is in the same order of magnitude as the RCS of the birds the radar is set to detect and record. Even thought the model aircraft equipped with a GPS receiver and video link provided the necessary freedom to move the test target around producing good GPS reference data for analysis, the drawback of the method was that the aircraft is a relatively complicated structure with a complex and unknown RCS. As opposed to the RCS of a conducting sphere, the aircraft RCS will vary substantially as a function of the radar wavelength and the aspect angle. This is due to the irregular shape and positioning of the different scatterers inside and outside the balsa tree fuselage. An important prerequisite when using the model aircraft as a test target was therefore that its RCS was measured and verified for all the relevant aspect angles and radar wavelengths. This was performed using a special RCS measurement set-up in the anechoic chamber in the NTNU/SINTEF laboratory for antenna measurements. **Figure 53** below shows the model aircraft mounted in the lab, and has an example of a 360° S-band RCS measurement.

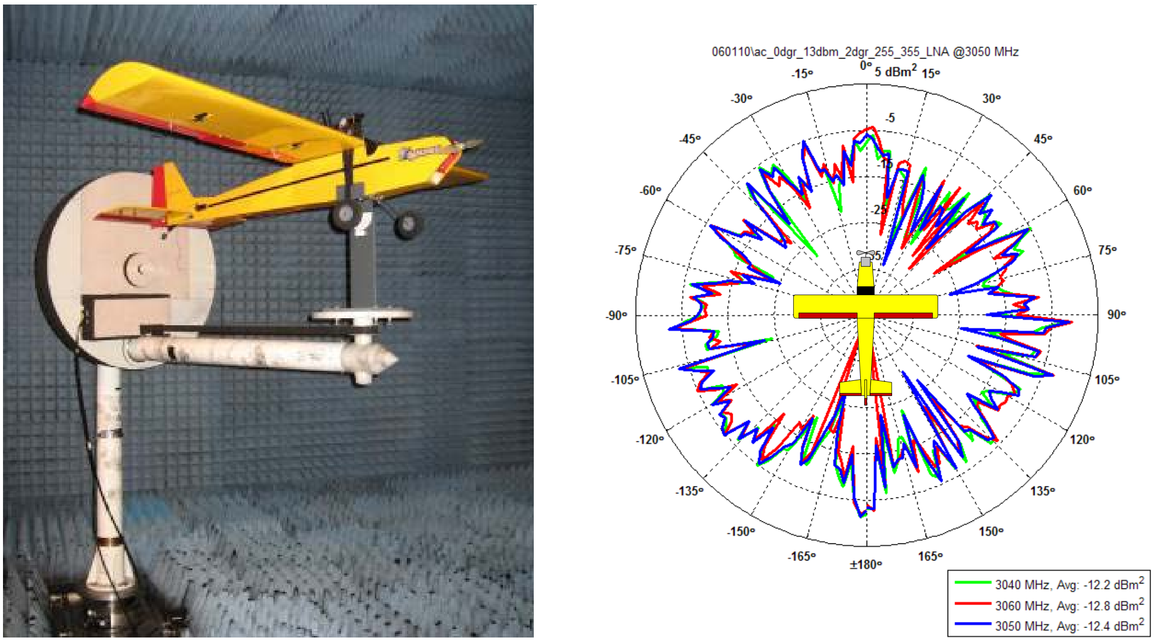


Figure 53. *Model aircraft used as test target mounted on the swivelling table on the measurement tower in the anechoic chamber. Measured S-band RCS on the right.* Photo: Yngve Steinheim.

6.5.3 Performance test results

One of the important tasks to perform initially was to align the horizontal radar with the environment so that the digital target data was reported with its correct geographical position. To do this the target data recorded in the radar was compared to GPS data, and the offset was estimated and compensated for. **Figure 54** illustrates an example of recorded radar tracks together with the GPS aircraft position data. In addition to low visibility in parts of the route, this example clearly indicates that there is a position offset between the radar reports and the GPS data from the test aircraft. This information is used to perform proper alignment of the radar.

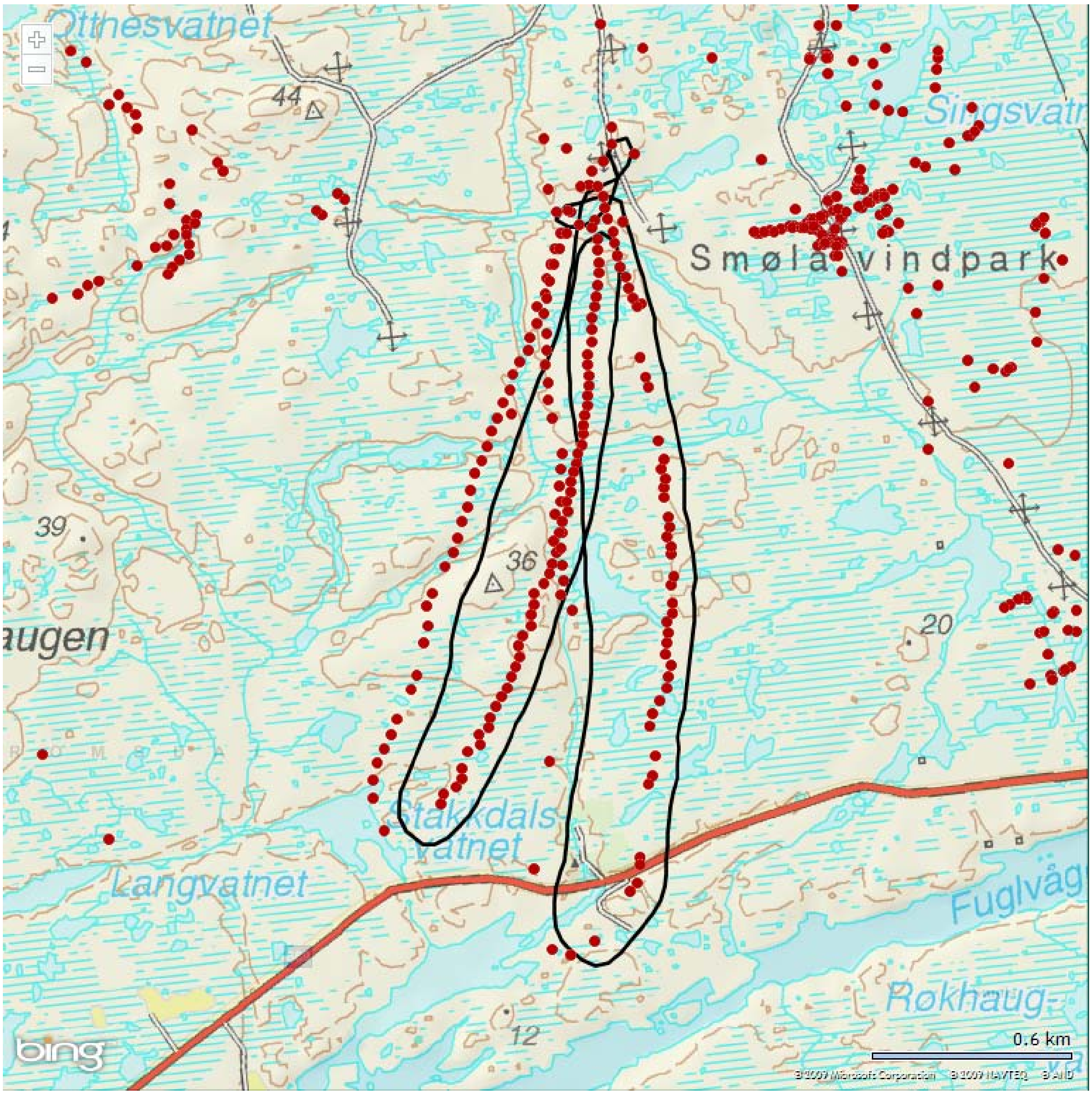
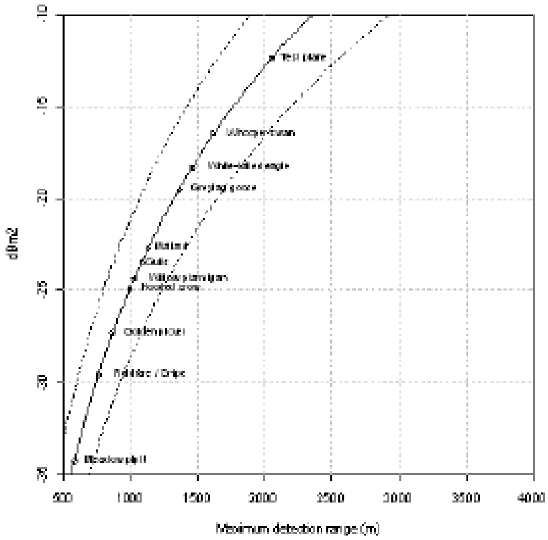


Figure 54. *Radar tracks (red dots) together with the corresponding GPS position of a model aircraft (black solid line) used for radar-performance testing.*

Because of a highly cluttered environment, the probability of detection (P_d) is generally lower than in the clear in the whole coverage area. The maximum detection range has been estimated combining 5 different test-flights (tracks) of the model aircraft in **Figure 55**.



Figur 55. *Probability of detection of the test aircraft as a function of range. The grey bars indicate the actual binned data and visually assessed detection range (2350 m).The superimposed smoothed lines indicate the modelled effect and the detection range at P_d=0.5 (2050 m, range: 1650 2550 m).*

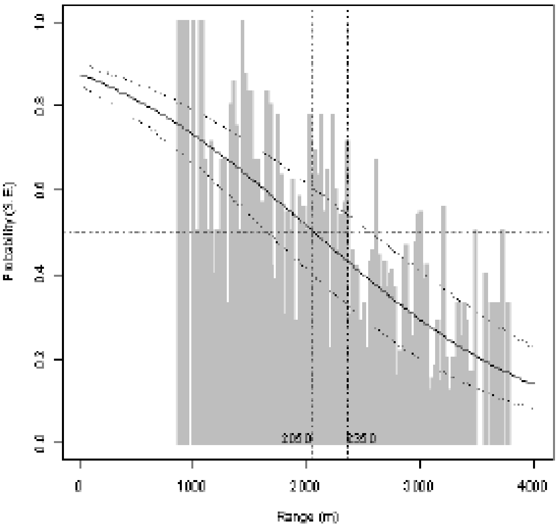


Figure 56. *Estimated detection range (P_d=0.5) for different bird species based on the modelled detection range of 2050 m. The striped lines indicate the uncertainty in the estimated detection range (S.E.).*

The clutter reduces the probability of detection inside the clutter patches in the coverage area, and the result is that the probability of detection is not a smooth function of range, but **Figure 55** clearly indicates that it is decreasing with range. And the point where we have P_d=0.5 for the test aircraft lies between 2050-2350 m. With this information, and since we know the aircraft RCS and the theoretical RCS of different bird species, we can use the radar equation and extrapolate some estimated detection ranges with the horizontal S-band radar for different sized birds. From **Figure 56** we see that we should expect to be able to follow the WTE with a P_d of 0.5 out to about 1500-1700 m. That will give a coverage area about 3000-3400 m in diameter for this particular species.

6.6 Large-scale 3D radar

NINA/SINTEF has inquired into the possibility of using the long range 3D radars of the Royal Norwegian Air Force and the Norwegian Meteorological Institute for mapping of large scale bird migration along the Norwegian coastline. The feedback from both agencies in initial meetings has been positive, but they pointed out that they will only by capable of supporting NINA with radar-data products and cannot commit any manpower to the project. The military data is generally classified according to national security regulations, and the most critical issue to be resolved before access can be granted, is how the data can be filtered and declassified for use by NINA. NINA has received a formal written permission to start a pre-study to find and test suitable methods and procedures of how the necessary data can be extracted and released for open research. However, the military authorities have reserved the right to evaluate the outcome of this study before a final permission for the use of military data is granted.

6.7 Preliminary conclusions and remaining questions

Conclusions:

- Avian radar is not a tool that can be utilized without any knowledge on both the technological, methodological and biological aspects concerned. We have developed various practical methods/tools to aid radar personnel to ease localisation, set-up and calibration of radar equipment, as well as provide protocols to handle data analysis. Then, avian radar may provide many new insights into bird behaviour, not in the least connected to possible effects of wind-power development – both in the pre- and post-construction phase.
- Analyses from Smøla visualize, for example, fluxes of spring/autumn migration, specific bird behaviour, possible collision tracks and provides improved ways to analyze avoidance behaviour at a fine spatial scale.

Remaining questions:

- Avian radar can provide near real-time information on bird activity. This may be used to identify periods and/or areas with increased risk for collisions. What remains to be done is to develop a collision risk model based on these data; rendering insight into higher levels of bird activity at rotor-swept height at each turbine at any given time. If this model may prove to have predictive power, when verifying with recorded casualties, this may be utilized to warn wind-power plant personnel to idle turbines.
- The data collected from April 2008, and onwards, needs to be analyzed with respect to correlates with time-of-year, time-of-day and especially weather (e.g. wind speed and direction, visibility, etc.). Comparing these patterns with correlates between recorded casualties and for example weather parameters (especially wind speed) may form the basis to define mitigation measures such as idling turbines in given pre-defined situations.
- The MERLIN avian radar employed at the Smøla wind-power plant only renders insight into local patterns in bird activity. Especially for wind-power plants along the Norwegian coast, improved knowledge on large-scale migration routes will be important. Utilizing the large-scale 3D radar systems, employed by the Royal Norwegian Air Force and the Norwegian Meteorological Institute, to extract birds from their signals will be important. Nowadays our knowledge on bird migration routes are largely based on recoveries of ring-marked birds.

7 Methods and technology to mitigate bird mortality

Subproject responsibility: Kjetil Bevanger, Lars Johnsen

Objective: Assess the current knowledge on the effectiveness of tools and technology that may reduce bird mortality in connection to wind-power plants and - based on the review conclusions – suggest concrete actions to mitigate the WTE mortality within the SWPP.

7.1 Background

At the Statkraft/NINA meeting May 9 2006 it was decided that NINA, together with SINTEF, should outline a pilot study to obtain knowledge on visual/auditory techniques and tools to reduce the bird collision risk in connection to the SWPP. The WTE should be the main target species for the research. The project had two modules: a literature review (NINA) to evaluate previous attempts, and a feasibility study of available technical solutions and the possibilities for developing new tools to mitigate the eagle collision problem (SINTEF).

The SINTEF part of the pilot study was carried out by the *Department for Communication Systems* and the *Department for Optical Measurement Systems and Data Analysis* within the SINTEF Research Unit ICT (Information and Communication Technology). These two departments should focus radar and visual/auditory techniques respectively. The outcome of the “radar-study” is described in paragraph 6, and will not be commented further.

The study on ”Auditory and visual techniques”, was divided into three phases:

1. Pre-study
2. Camera based system - implementation
3. Camera based system - suggestions for further work and visual mitigating measures

The main conclusion from the Pre-study (Kolås & Johnsen 2007) regarding the *Auditory part* was that birds will 1) habituate to “scare crow” measures, and 2) the audio pollution will create another problem. Thus no suggestion on further activities was suggested. Regarding the *Video surveillance part* it was concluded that acquiring knowledge on bird behaviour near wind power installation is important, and a video monitoring system would also have the potential of further development into an “Early warning system” that could give input to visual “scare crow” systems and/or the possibilities for shutting down of individual turbines during collision hazard situations, i.e. when WTEs appeared close to the turbines. Regarding the possibilities for visual mitigating measures three area of interest were identified:

1. Enhancing the visual appearance to counter motion smear (see **Figure 63**)
2. Limiting “visual pollution” by operating in UV
3. Utilize motion smear to enlarge the appearance of 1 and 2

Statkraft agreed to proceed with Phase 2, and the implementation started in autumn 2007, after a contract between SINTEF ICT and NINA had been signed on October 10 (”*Fugler og vindmøller, Fase II, implementering-overvåking/deteksjon med kamera*”). The contract budget was approximately 1 million NOK. The contract specified the following deliveries:

- Local computer with temporary storage
- Software system for selective storage of sequences with moving objects suspected of being birds
- Prepared for further development, e.g. 2D and 3D coordinate
- Ethernet access for remote control and communication
- One daylight camera

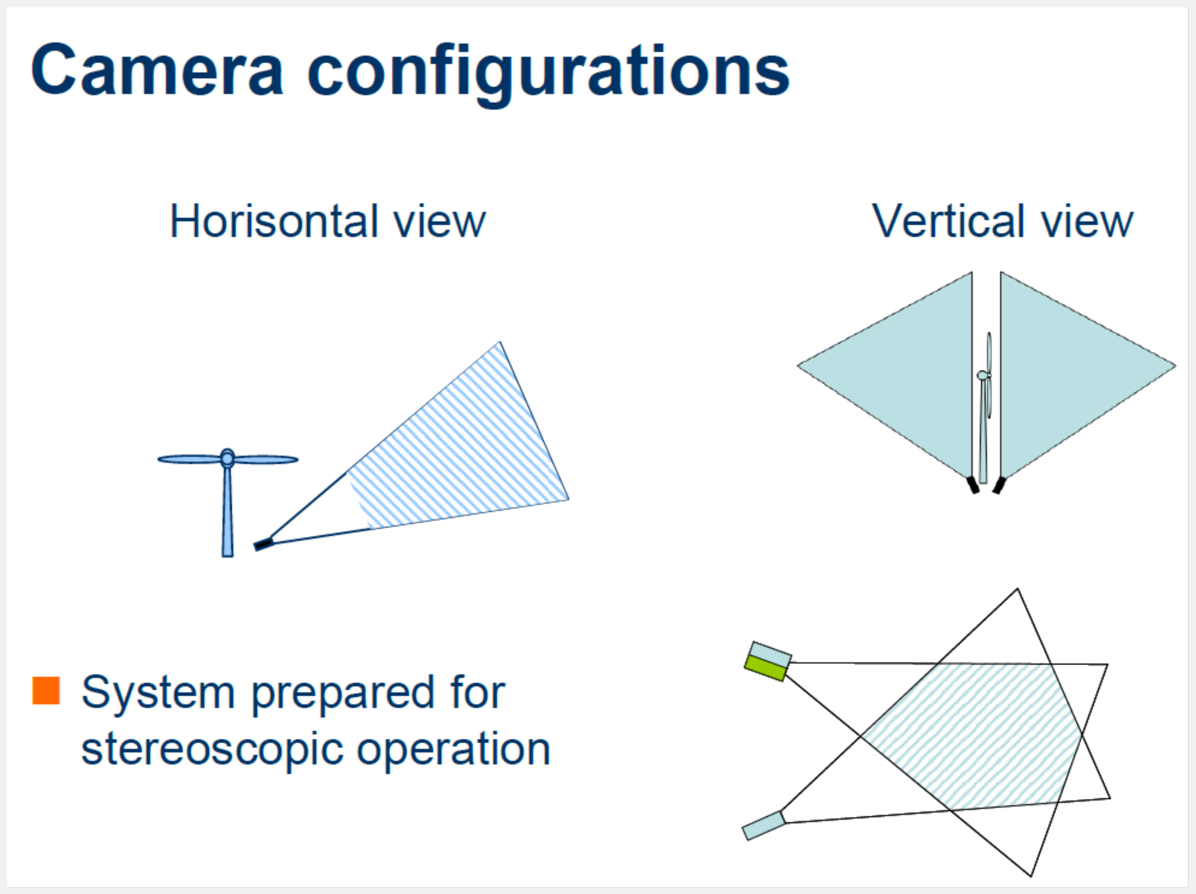
- One thermal camera for night vision

According to the time plan a full installation should be up and running 24 weeks after project start. The system was up and running 35 weeks after project start within the budget frame with the following deliveries:

- Local computer with temporary storage
- Software system for selective storage of sequences with moving objects suspected of being birds
- System prepared for further development
- Ethernet access for remote control and communication
- Automated software for uploading of stored video to central server
- Seven simultaneously operating cameras
- Six daylight cameras, 3 Mpix / 6 fps
    - Three vertical looking with two mounted as stereo pair
    - Three horizontal looking with two mounted as stereo pair
- One horizontal looking thermal camera, 320x240 pixels / 6 fps

In April-June 2008 the 7 video cameras were installed in the vicinity of turbine no. 43 (**Figure 57-61**). The 6 normal daylight cameras were installed with three cameras looking up along the turbine tower, and three looking forward - away from the tower. This would allow a detailed monitoring of the WTE (and other species) behaviour close to the turbine and at the same time allowing data collection on the bird in-flight pattern towards the turbine. Regarding the field of vision of both the upward and forward directed cameras, two of the cameras were oriented in a manner that would make later stereo picture check possible and thus a full 3D object positioning. The FLIR camera would give supplementary information.

All cameras were protected to stand outdoor operations. Those directed vertically were built into an outside protective house with heated, rotating window to retain full sight even during snowy or rainy conditions. All data were transferred via Internet to a server in NINA. The raw data were temporarily stored on a hard disk in turbine 43.



Camera configurations

Horisontal view

Vertical view

- System prepared for stereoscopic operation

Figure 57. *Configuration of cameras installed in connection to turbine 43 in the SWPP*. Drawing by Lars Johnsen.

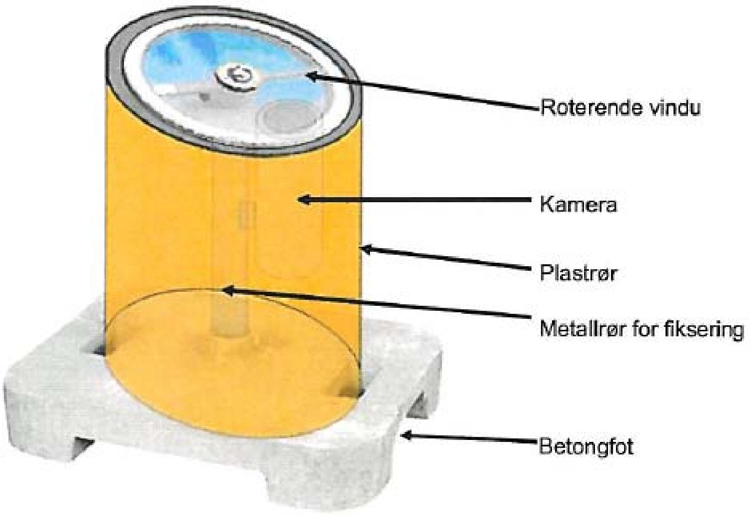


Figure 58. *Sketch of upright pointing camera. The camera is placed on a centre tube and protected by a protecting tube. On top a heated rotating window (2000 RPM) secure free sight by keeping rain and snow away.* Drawing by Lars Johnsen.

Figure 59. *Camera system installed in connection to wind turbine no 43.* Photo: Kjetil Bevanger.

Figure 60. *Upright pointing camera with rotating window.* Photo. Kjetil Bevanger.

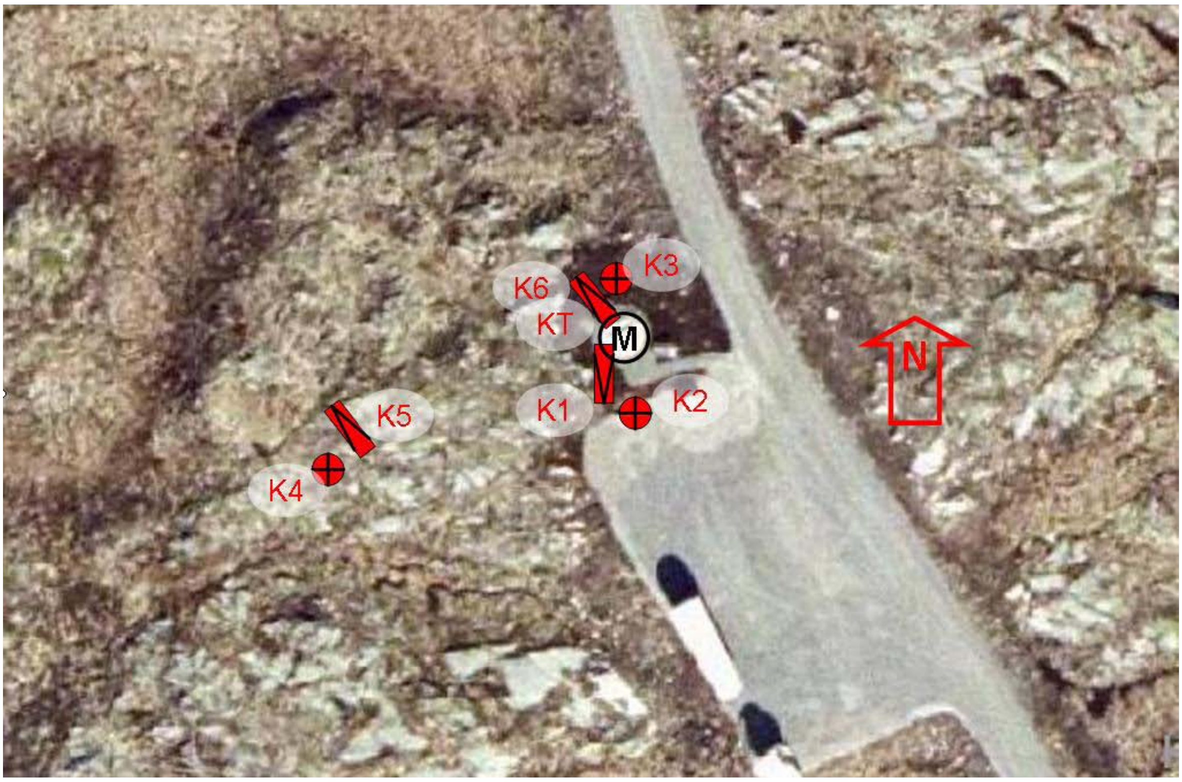


Figure 61. *Approximate camera positions around turbine no. 43 in the Smøla Wind-power plant. Photo accessed from "Gule Sider®".*

Figure 62. *A gull passing wind turbine no. 43 in the Smøla Wind-power plant as captured by camera 5 on 2008-05-27 12:50:40.*

7.2 Mitigating project, phase III

Based on discussions between Statkraft, NINA and SINTEFD during summer and autumn 2008, the following key questions were identified:

- Is bird mortality related to wind turbines mainly a function of collisions with the rotor blades?
- Are some birds colliding with the turbine-supporting structure (the tower)?
- To what extent is collision risk affected by the turbine speed?
- Is the flight performance of a bird affected by the turbine-generated turbulence?
- Are birds trapped in turbulence outside its control due to body biomechanical constraints and thus being dragged towards the rotor blades?
- Is the turbulence-created vortices and air pockets with increased/lowered air pressure obstructing lift resulting in a free fall to the ground and fatal injuries?
- Are WTE collisions due to the fact that the birds do not perceive/see the rotor blades (motion smear)?

Thus, the overall conclusion was that it is a prerequisite to learn more about the species-specific bird behaviour close to the turbines to take the correct decisions on what mitigating measures to proceed with. *In situ* experiments are very expensive, and would be difficult to justify unless based on a sound ecological and biological understanding of what the collision triggering factors are tied up to. It was agreed to work out project proposals that could make a basement for addressing these questions in more detail, including a project enabling a sound analysis of the camera data base. In 2008 project proposals on

1. Camera shortcomings (false alarms and data processing) (Thielman 2008)
2. Camera duplication (Johnsen 2008a)
3. The effect of turbine-induced air turbulence on bird behaviour (Meese 2008)
4. Making wind turbines more visible using UV-light (Johnsen 2008b)

were worked out by SINTEF. Due to the costs involved in a possible implementation of the projects, the overall conclusion from a meeting between Statkraft, SINTEF and NINA was that the issue on mitigating measures, including camera systems, had to be postponed, as BirdWind only had one year left before the activities had to close down. The rationale behind these proposals is summarized in the following paragraphs.

7.2.1 Camera shortcomings

Although the installed camera system has been operating well from a technical point of view, the number of false signals triggering the camera to operate was very high, making a cost-effective data processing impossible. The reason is that the system has a malfunction being triggered by other movements than by birds. That was the background for the proposal on automatic video analyses of bird movements, which would provide significant improvement in the search efficiency, significant reduction in disk storage requirements and automated analysis of bird movements (cf. Thielman 2008). In short the project objectives was to obtain

- A significant reduction in number of stored false positives
- Bird position tracked over time and their 3D positions calculated where possible (S/N ratio in recordings)
- Discrimination between WTE and other birds based on characteristics (size, form, wing frequency, flight pattern)
- Suitable tools for visualization and use of the filtered information (e.g. search for all recordings of eagles with given flying direction or pattern)

Another issue was that with sufficient reduction in false positives the system could function as an “Early warning” for activation of mitigating measures.

In 2009 Statkraft invited Astraguard (http://www.astraguard.com/) to evaluate the possibilities for a solution to process the Smøla video data in a way that could filter false positives, leaving only the pictures were birds were present. At the BirdWind 2010 Annual Meeting on Smøla March 22 Akkadia/Astraguard gave a presentation on "*Alternative solutions for camera monitoring*". It was decided that NINA should provide Astraguard with video samples, to test the possibilities for automatic picture processing. The software SINTEF used in connection to the Smøla camera system was delivered by Detec (http://www.detec.no). In August 2010 an e-mail discussion between SINTEF, Astraguard and NINA concluded with the fact that it is not possible to use the Detec software for the original intended purpose of selecting picture of birds only. In a final comment SINTEF says (as a response Astraguard) that "- - *detecting these birds will require something else than off-the-shelf software solutions - -.*" Thus, for the time being several terabytes is resting with NINA waiting to be analysed.

7.2.2 Camera duplication

The second project proposal related to the fact that having camera installations only at one turbine was reducing the probability for obtaining a sufficient amount of data, and SINTEF was asked to make an estimate of the cost connected to duplicating the camera installations (cf. Johnsen 2008a).

7.2.3 The effect of turbine-induced air turbulence on bird behaviour

Questions relating to biomechanics have close connection to wind turbine induced bird mortality. In a application to the RENERGI Programme in 2005 (Bevanger et al. 2005) these questions were dedicated an own work package "*Technical aspects, e.g. physical construction of the wind turbine, turbulence and vortices created by the rotor blades (i.e. changed aerodynamic conditions) and development of automatic bird collision monitoring systems*". It is a prerequisite to understand how birds experience the airspace close to a wind turbine based on the species-specific biomechanical abilities. Thus it was important that the project focused could focus on technology that could detect birds in the close vicinity of the turbines and return information on bird behavioural responses. Without detailed knowledge on the possible effects of rotor-induced air turbulence it is difficult, from a scientific point of view, to answer basic questions connected to e.g. collision risk and why some species are more likely to be killed by the turbines than others. Such knowledge could also generate more general technical solutions to reduce or prevent collision risk. That was the reason why NINA asked SINTEF to work out a project proposal where aerodynamic responses to wind turbines bird could be studied in a wind tunnel facility at SINTEF (cf. Meese 2008).

Unfortunately the present knowledge regarding turbulence intensity close to the turbines is limited, and noting is known on how local topography contributes to modify the turbulence patterns. From a biological point of view each bird species has specific aerodynamic characteristics, deciding its ability to operate in the air and avoid e.g. artificial obstacles like wind turbines. Combined with their visual abilities this is central parameters regarding the ability to identify - and avoid - by making swift avoidance manoeuvres - unexpected air obstacles (Bevanger 1998).

Knowledge on the species-specific ecological factors and life history parameters is a prerequisite as well. Some species spend a lot of their time in the air, e.g. during courtship display or hunting activities, while other species mainly stick to the ground. It is a well known phenomenon that raptors use bubbles with rising, hot air (thermals) to gain height, by which they save energy. The WTE seems to conduct a sort of "display" in the vicinity of the rotor blades and approaches the airspace in the turbine vicinity consciously. A possible explanation to the fact that the eagles seems to "play" close to the rotor blades is that they may experience the turbulence as a sort of thermal lift. It is also known that wind turbines creates significant variations in air pressure in their vicinity, and it is known that bats are exposed to barotrauma (Baerwald et al. 2008), i.e. the lungs are ruptured when approaching certain positions relative to the rotor blades due to air pockets with lowered air pressure.

At the SWPP the WTE and the willow ptarmigan have the highest recorded mortality. These two species are highly different with respect to perception abilities as well as biomechanics. The WTE is a highly aerodynamic fit species with a sharp vision, while the willow ptarmigan is characterized by being a poor flyer with a less sharp vision. As such they represent two model species that can contribute to identify key parameters connected to wind turbine bird mortality risk.

7.2.4 Making wind turbines more visible - bird vision

At the outset the bird vision issues should be the main responsibility of Olle Håstad at the University of Uppsala/Bristol, being part of the project application team in 2006. The application text stated that "*Test and development of deterrent measures will focus on visual and auditory stimuli, or a combination of both. Every animal that has been tested (mammal, fish, insect or, in the case of birds, pigeons) has motion-sensitivity that is greatest at long wavelengths. In humans, motion detection is driven by the L+M cone response (i.e. luminance pathway); in bees it is the MW (green) receptors (i.e. the longest wavelengths to which they are sensitive); in birds it is consistent with the double cone response. UV-coatings are likely to be fairly unimportant for increasing the visibility of moving objects like wind turbine rotor blades (cf. Young et al. 2003, I. Cuthill pers. comm.). It is, however, possible to make the blades more visible to birds, by minimizing motion smear. Experimental laboratory studies indicate that painting one of the rotor blades black, or with a certain black striped pattern, may help to decrease the motion blur (cf. Hodos 2003). A full scale experiment using wind turbines at Smøla will be carried out to test whether this will reduce the bird collision rate or affect bird flight behaviour*."

This part of the project was not activated beyond the project kick-off meeting on Smøla 26.-27.03.2007. However, Statkraft maintained a direct communication with Olle Håstad and decided to contribute with separate funding for research activities in connection to an offshore wind power project in Sweden. The intention was to coordinate this activity with the BirdWind activities on Smøla.

In June 2008 Håstad sent Statkraft a "*Project plan: An accurate model for calculating wind turbine visibility to birds*". The project did, however, not reach an operational stage as Statkraft and the University of Uppsala not reached a final agreement on some formal juridical questions. In December 2009 Statkraft notified Håstad that the project had to be postponed as the bird vision and mitigating measure issues would be discussed within the framework of a possible BirdWind 2 project.

The question of making a wind turbine rotor blade, as well as the tower structure, more visible, is closely related to the ability of birds to perceive their surroundings. Bird survival is strongly affected by visual capacities, and bird species are highly diverse with respect to eye structure. Bird eyes are specialized instruments, and in general the visual acuity is 2-8 times higher than a mammal eye. Visual fields are up to 360^{O}, and stereopsis ranges from 0^{O} to 70^{O} (e.g. Korbel 2002). Moreover, birds have a well developed colour vision, and it is assumed that birds see more colours than humans, and that the colours appear more saturated than they do to us. The reason is that birds have four (or more) cone types, and pigmented oil droplets in the photo receptors. While humans have short, middle and long (also called blue, green and red) cones, birds also have a UV-cone with a UV-perception from 320 nm (e.g. Butler 1996, Martin 1990, McIlwain 1996, Valberg 1998).

Birds are tetra- and pentachromatic (being able to differentiate between two different wavelengths of UV), compared to the human eye, which is trichromatic. This is a common ability of diurnal birds and due to their special UV-sensitive rods. This ability plays an important role in inter- and intra-specific communication based on plumage UV-reflection, and the ability to, e.g., identify/assess fruit ripeness based on varying UV-reflection of fruit wax layers. As such it is an important factor in understanding bird behaviour (e.g. Bennett et al. 1996, Cuthill et al. 2000, 2005, Siitari & Huhta 2002, Lendvai et al. 2005, Smith et al. 2005).

Based on the assessment that UV is not visible to the human eye, and that birds in general perceive within this part of the spectre, SINTEF (Johnsen 2008b) was asked to prepar a project proposal in 2008. The aim of this project was – by means of field experiments – to test weather UV spot lights have any effect on the behaviour of WTE approaching the turbines. The main rationale behind the proposal was to

- Limit “visual pollution” by operating in UV
- Enhance the visual appearance to counter motion smear
    - Tip speed:250 km/h
    - Motion smear at:10 deg/sec
    - Smear starts at about: 400 m
- Utilize motion smear to enlarge the appearance of countermeasures
- Repelling visual influence

Regarding implementation of a project focusing increased turbine visibility, this must be based on species-specific knowledge of the target species vision. It would be difficult - and probably characterized as irresponsible - to argue for huge investments for *in situ* experiments on Smøla without sufficient knowledge on the WTE eye. Possible actions have been discussed throughout the project period, and were a main focus during the 2009 BirdWind Annual Meeting.

Figure 63. *The human eye is unable to follow very fast movements of an object. That is probably a general shortcoming to the vertebrate eye, including birds. Usually this phenomenon is named motion smear.*

7.3 Preliminary conclusions and remaining questions

Conclusions:

- Although the subproject on methods and technology to mitigate the WTE mortality in the SWPP has not met its initial expectations, the findings and the increased understanding of the complexity reached during the project period, makes a firm basement for attacking these challenges at a later stage.
- To succeed with mitigating measures to reduce the collision hazard for the WTE and the willow ptarmigan, it is a prerequisite to increase the species-specific knowledge on how the behaviour of these species is determined by their vision, colour and movement sensibility, and at what distance visual stimuli is perceived.
- Increased knowledge on how birds, based on their biomechanics and aerodynamic skills, control the turbulence and vortices in the vicinity of the wind turbines is needed. Without this knowledge it is difficult to assess how e.g. the WTE view and understand the movements of the rotor blades and other wind-turbine associated structures.

Remaining questions:

- Increased knowledge on decisive parameters connected to species-specific biomechanics is needed. To modify a wind turbine towards a more bird-friendly design it is necessary to know how the rotor blade speed, and design modify the generated turbulence, and how these parameters are modified by local topography and wind conditions.
- A key issues to future research will be whether wind turbine-related mortality among birds is a function of collisions with the rotor blades or not, and to what extent the speed of the rotor blades affect the collision risk, as well as whether the flight path of birds are affected by the turbine-generated turbulence in a way that may be predicted.
- A next step will be to assess whether this is
    - caused by the bird not perceiving the rotor blades (motion smear)
    - or whether it is trapped in a turbulence outside its control due to body biomechanics and thus being dragged towards the rotor blades
    - or whether the turbulence creates vortices and air pockets with increased/lowered air pressure obstructing lift resulting in a free fall to the ground and fatal injuries
- By developing a functional camera system in the SWPP it should be possible to record data that could answer remaining questions on how the WTE and willow ptarmigan behave when being close to the turbines. Together with increased knowledge on their vision and biomechanics, possible changes in flight paths may be analysed and connected to perception parameters and local wind conditions (e.g. distance when the birds react, how fast they react, avoidance distance and avoidance behaviour). This enables an optimized use of the camera technology and support to the theoretical approaches regarding the importance of bird vision and aerodynamic abilities.

8 Data flow and storage systems

Subproject responsibility: Roald Vang, Stig Clausen

Objectives: Develop a comprehensive technical infrastructure for efficient data flow, storage, retrieval, management and analytical use of bird-detection data from installed camera systems and the MERLIN radar and applied satellite telemetry.

8.1 Data import

The avian radar system generates huge amounts of raw data when there is much activity around the SWPP. The raw data are processed in place and this result in two new Microsoft Access database files each day for the vertical and horizontal radar systems. Each night at 2am, a job is invoked, which transfers the files to the central file server located at NINA HQ in Trondheim. Then another job grabs these files, processes them, and populates the central database server with the new entries. This is a SQL Server 2008 Integration Services job (**Figure 64**).

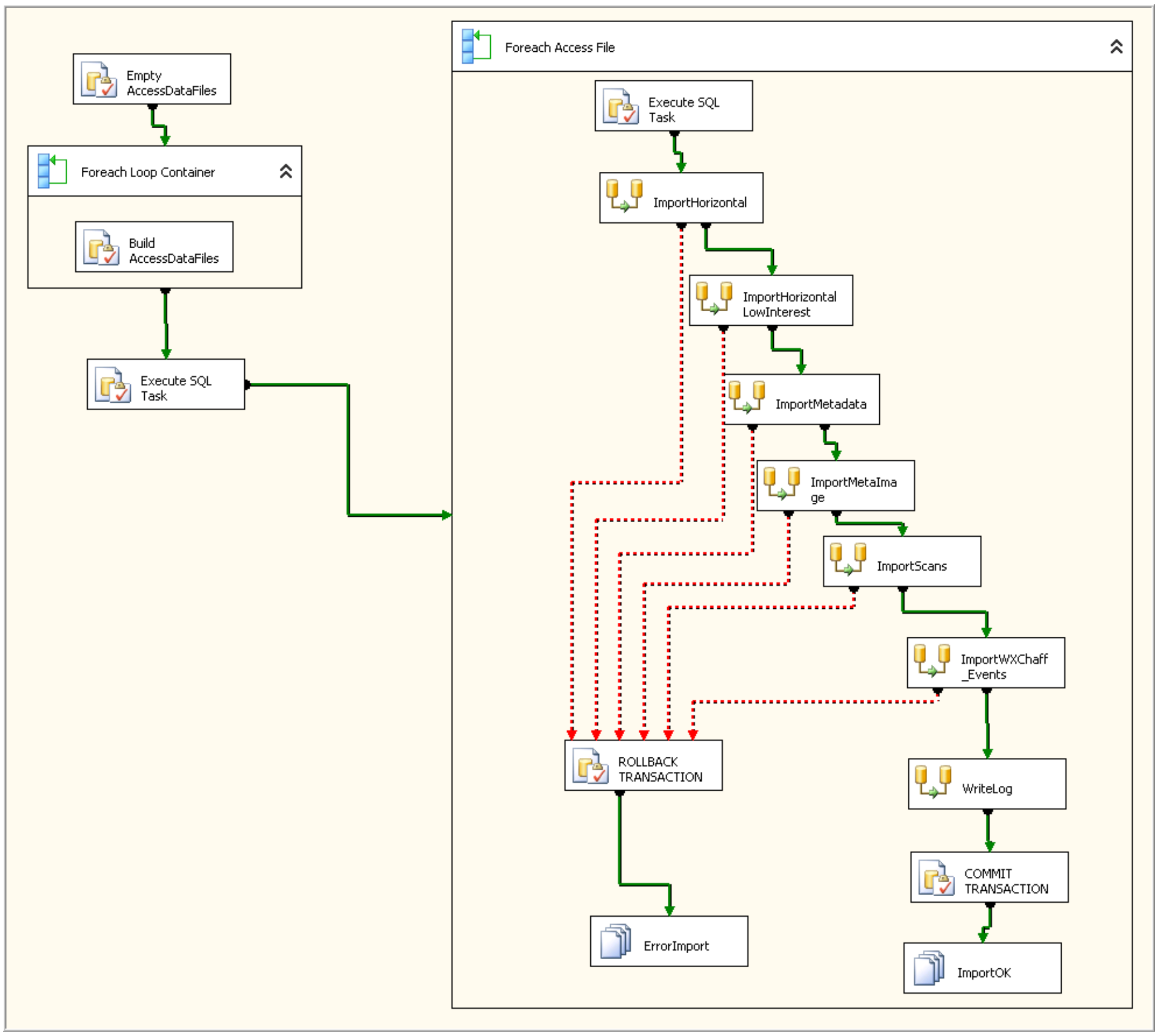
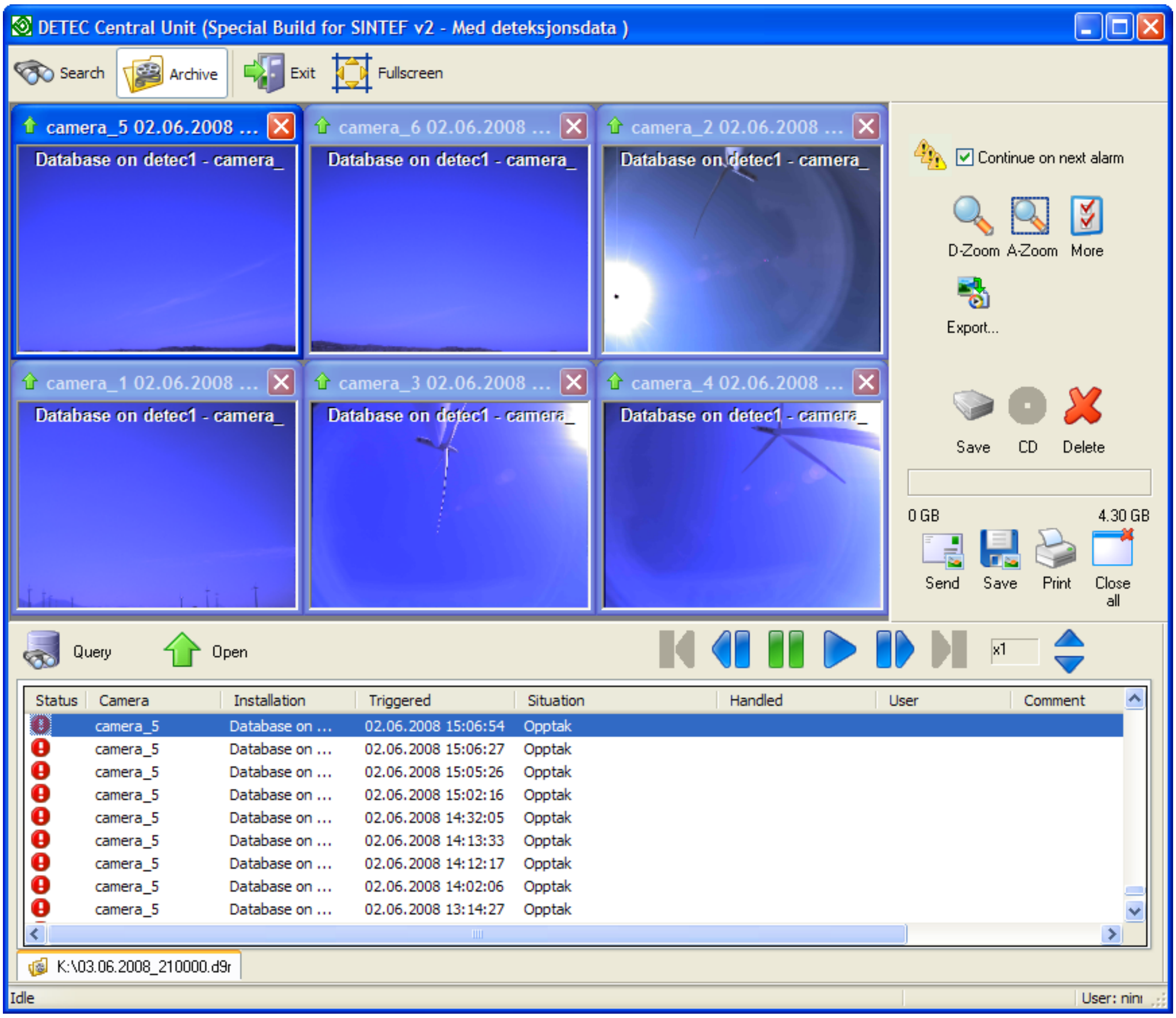


Figure 64. *Data import - SQL Server 2008 Integration Services.*

8.2 Camera images

The 6 cameras positioned around wind turbine no 43 (**Figure 61**) are also generating huge amounts of data as each camera is recording 6 frames per second (fps) when movement is detected nearby. Recorded data is daily transferred to NINA Trondheim, and stored in the connected storage solution. We have special viewing software to investigate the recorded images when they are transferred to the storage system (**Figure 65**). The avian radar and the camera systems are connected via radio links, which also provides the Internet gateway. A local Internet Service Provider (NEAS) provides the Internet connection from the radar/camera systems (10 Mbit/s). Between Smøla and Trondheim we have a site-to-site VPN tunnel for se-cure data transfer.



Status	Camera	Installation	Triggered	Situation	Handled	User	Comment
❗	camera_5	Database on ...	02.06.2008 15:06:54	Opptak			
❗	camera_5	Database on ...	02.06.2008 15:06:27	Opptak			
❗	camera_5	Database on ...	02.06.2008 15:05:26	Opptak			
❗	camera_5	Database on ...	02.06.2008 15:02:16	Opptak			
❗	camera_5	Database on ...	02.06.2008 14:32:05	Opptak			
❗	camera_5	Database on ...	02.06.2008 14:13:33	Opptak			
❗	camera_5	Database on ...	02.06.2008 14:12:17	Opptak			
❗	camera_5	Database on ...	02.06.2008 14:02:06	Opptak			
❗	camera_5	Database on ...	02.06.2008 13:14:27	Opptak			

Figure 65. *Screenshot of DETEC Central unit, software to view recorded images.*

8.3 Central storage system

The storage system consists of an HP ProLiant server with two SAN-attached disk enclosures with a total capacity of 8 TB. The storage server is running Microsoft Windows Server 2003 Storage Edition and EMC DiskXtender for Windows which offers highly scalable data management to enable a tiered storage strategy. EMC DiskXtender for Windows transparently migrates inactive or infrequently accessed files to a HP StorageWorks MSL4048 Tape Library which offers up to 76.8 TB of storage, without changing the user's view or access. It provides a best practice file archiving solution through the ability to migrate files to the archive storage device, adding flexibility as well as extra layers of protection for archived data. DiskXtender for Windows assists us in reducing storage costs, simplifying capacity management, ensuring consistent data-retention policies, and locating files quickly when needed for future analysis. The database server is an HP Proliant server with two dual core processors and 8 GB RAM, running Microsoft SQL Server 2008 on Windows Server 2003. SQL Server 2008 provides the highest levels of security, reliability, scalability and also spatial capabilities by using the support for spatial data.

The data flow infrastructure was established in 2008, and has been working as intended. However, we have seen the need to "tune" the data flow, and also to split the data into more fragmented databases and file systems to gain better performance when querying against the most interesting parts of the data. The tracks database is growing very fast (several hundreds of millions records) and with these amounts of data, filtering and splitting of the data is essential.

As a part of the data-mining task described earlier we have also installed Microsoft SQL Server Analysis Server 2008 so that we can utilize the powerful data-mining features inside SQL Server. We have created several data-mining models to use with the data, and tried to correlate the different types of radar tracks (birds, ground clutter, rain clutter, etc.) with for instance the different clusters produced when using the Microsoft Clustering Algorithm.

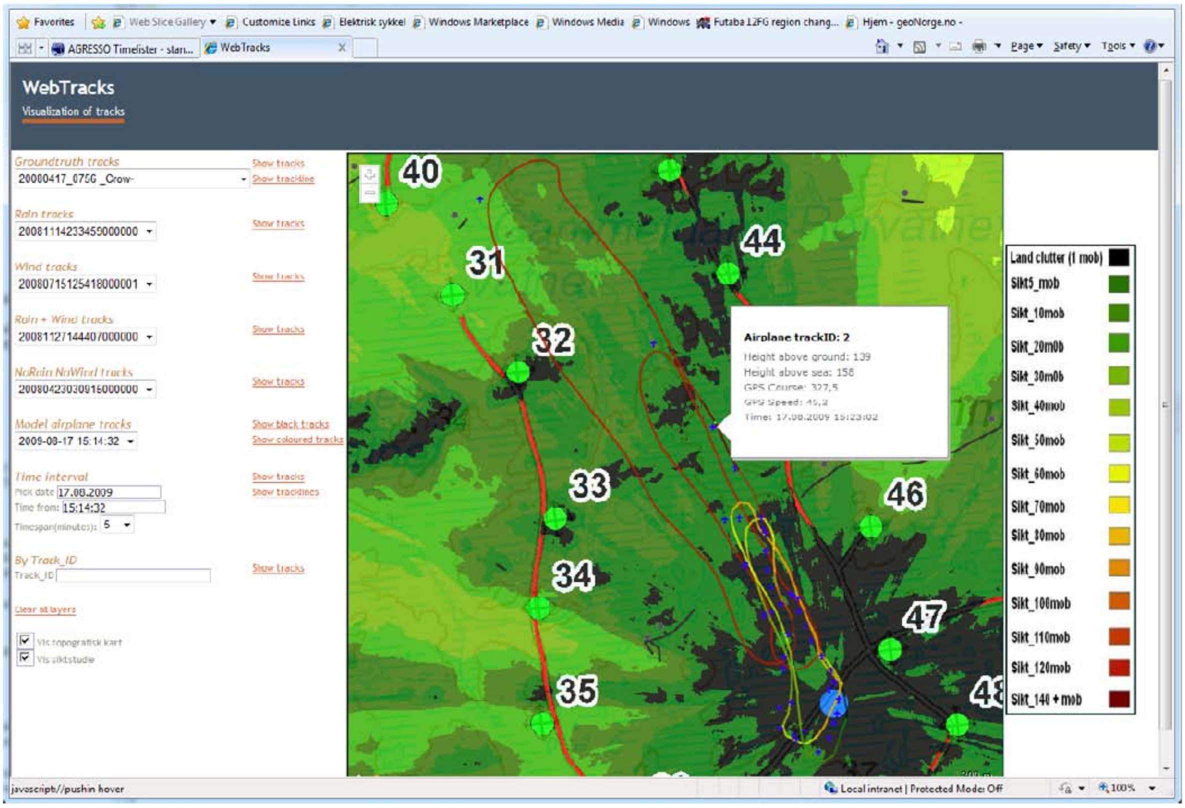
We have also imported weather data from The Norwegian Meteorological Institute, which we try to attach to the data when using the mining models.

8.4 Visualization of radar tracks

NINA has developed a web application, "WebTracks", which allows radar tracks to be visualized together with ground-truth data, weather data and tracks from model-aircraft tests (**Figure 66**). At the moment it is only used as an internal web application. It gives an instant view of where the radar might have low visibility. It also visualizes where the radar loses track of the object, and splits tracks into multiple segments, where they should have been contiguous.

By selecting and displaying ground-truthed data, or model aircraft tracks, together with tracks from the radar database in the same time interval, an instantaneous overview of the radar-tracking capabilities can be obtained.

It is possible to overlay both topographical maps, and clutter maps in the map window of the application. Together with colour coding of the objects height, the clutter map indicates where the object should be visible for the radar.



Groundtruth tracks: 20080417_0756 _Crow-
Rain tracks: 20081114233459000000
Wind tracks: 20080715125418000001
Rain + Wind tracks: 20081127144407000000
NoRain NoWind tracks: 20080423030916000000
Model airplane tracks: 2009-08-17 15:14:32
Time interval
Pick date: 17.08.2009
Time from: 15:14:32
Timespan(minutes): 5
By Track_ID
Track_ID:
☑ Vis topografisk kart
☑ Vis siktstudie

Airplane trackID: 2
Height above ground: 139
Height above sea: 158
GPS Course: 327,5
GPS Speed: 45,2
Time: 17.08.2009 15:23:02

Figure 66. *Screenshot of the WebTracks web application*.

9 GIS, visualization and terrain modelling

Subproject responsibility: Frank Hanssen

Objectives: Visualize the bird real activity patterns in 3D, establish a methodology and model possible conflict areas between birds and wind-power plants.

9.1 Introduction

Most of the efforts in this subproject have focused on terrain modelling, line-of-sight studies and ground-clutter modelling. These activities have made important contributions to the radar localisation process and tagging of potential false tracks inside theoretical land clutter areas stored in the MERLIN Horizontal database.

9.2 Analysis

As the MERLIN horizontal radar does not detect elevation of bird tracks we have not yet been able to visualize bird behaviour in 3D. A number of WTEs on Smøla will however be equipped with 3D GPS in 2011 and we hope to correlate some of these 3D GPS bird tracks with the MERLIN horizontal database in order to study and visualize the detected bird activities in 3D as originally planned.

9.3 GIS-tools

For ground-truthing purposes we designed a GIS-based sector map tool for ArcGIS 9.3 that produces user-adaptable background maps for the MERLIN horizontal radar interface (**Figure 67**). Predefined sectors (30 degrees at 500, 1000 and 1500 meters distances) centred on selectable vantage points can easily be added to the background map. The purpose was to facilitate the operator and the ground-truthing personnel to communicate about where to look for incoming birds. The horizontal radar interface can be used both by the operator and the ground-truthing personnel anywhere in the wind-power plant using a rugged laptop with mobile internet and remote desktop.

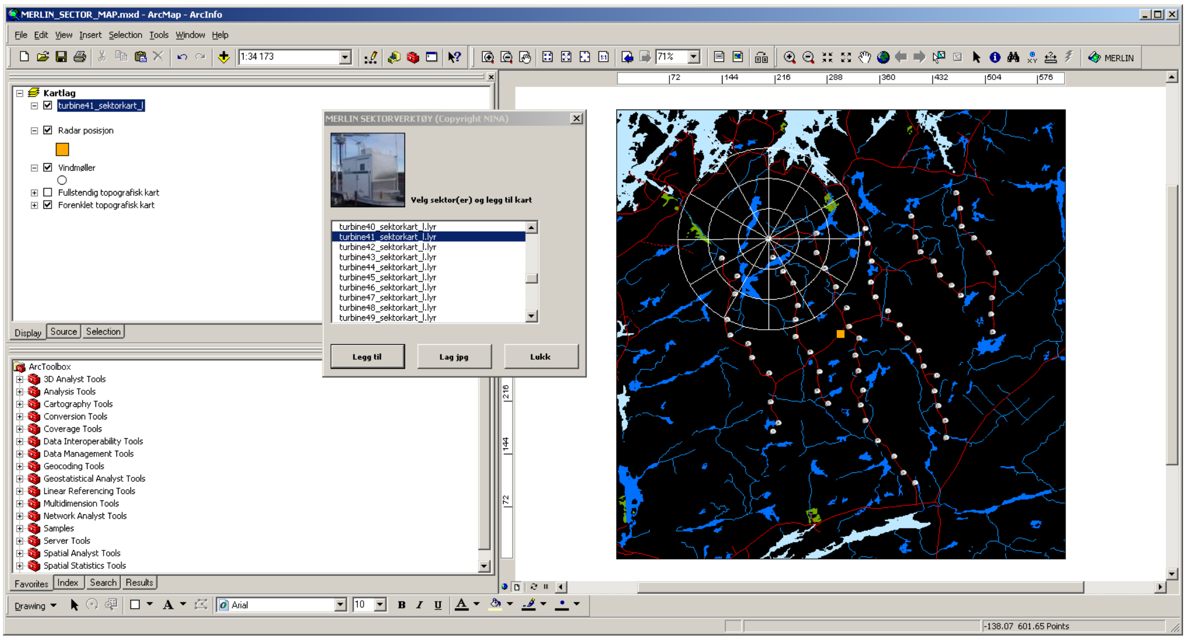


Figure 67. *Sector map tool for ground-truthing purposes. This is GIS-based sector map tool for ArcGIS 9.3 that produces user-adaptable background maps for the MERLIN horizontal radar interface.*

9.4 Terrain modelling

The national DTM25 (developed by the Norwegian Mapping authority) has been derived from vector elevation data (N50). The pixel resolution of DTM25 is 25x25 meters, which is considered too low for our purposes.

The first DTM we developed in ArcGIS 9.3 was derived from uncompleted high resolution vector elevation data (elevation contours, elevation points, lake and coastal contours and rivers) established in the mapping project Geovekst Smøla. This DTM was established as a TIN (triangulated irregular network). A TIN is a vector data structure that partitions geographic space into contiguous, non- overlapping triangles. The vertices of each triangle are sample data points with XYZ values. These sample points are connected by lines to form Delaunay triangles. The TIN was at the end converted to DTM5 (as a GRID with 5x5 meter pixel resolution).

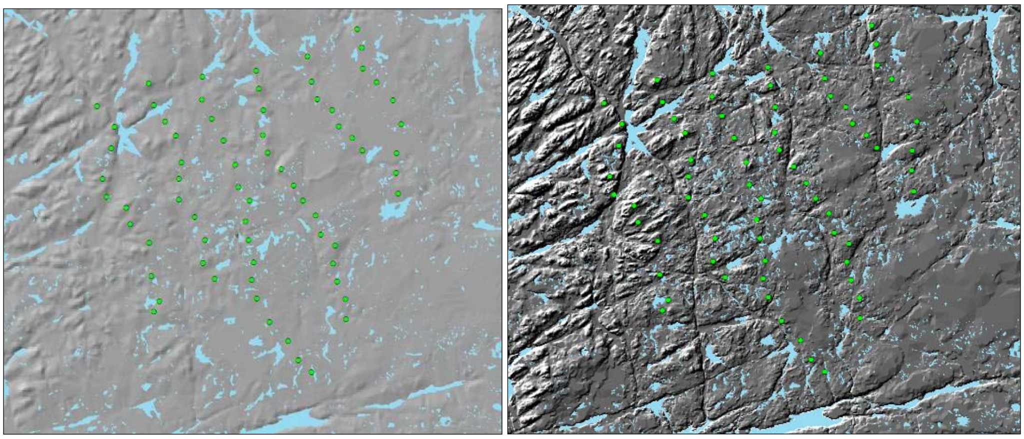


Figure 68. *Comparing DTM25 and DTM5 using hillshade The figure illustrates the difference in quality and resolution of the two terrain models*.

The DTM5 developed in ArcGIS 9.3 was derived from uncompleted mapping data with different precision levels (the Norwegian mapping standard FKB B and C). This introduced weaknesses in the model even though it is considered much more accurate than DTM25 (**Figure 68**).

A LIDAR scanning was performed by the GeoVekst Smøla project autumn 2009 with an average point spacing of 0.5 meters and approximately 2 ground points per square meter (**Figure 69**). All ground points (category 2) were interpolated into a Terrain which is a multiple-resolution, TIN-based surface built from measurements stored as features in a geodatabase.

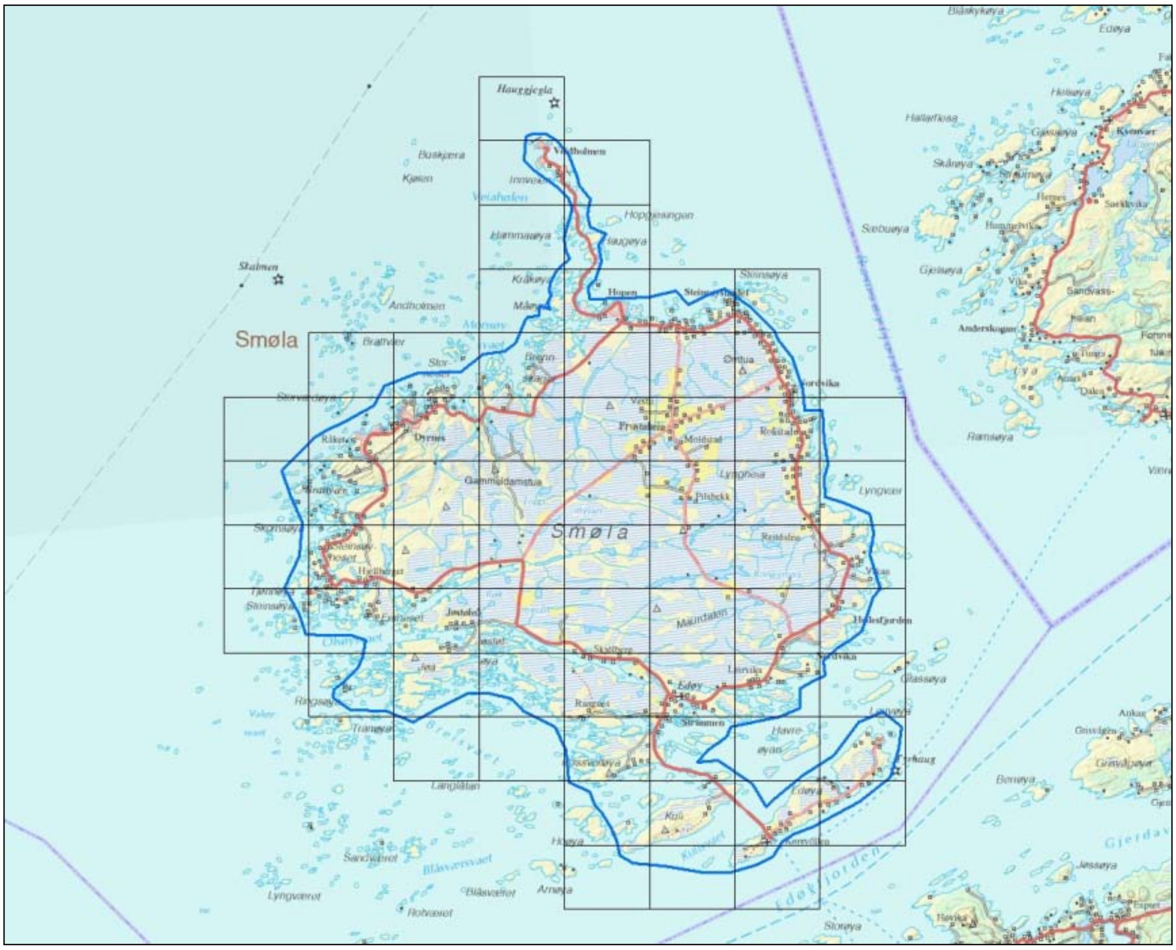


Figure 69. *The LIDAR scanning project at Smøla (blue outline displaying the project area).*

The Terrain was then converted to DTM1 (**Figure 70**) (as a floating point GRID with 1x1 meter pixel resolution). Pixels covering lakes/sea areas were masked with water polygon features from Geovekst to avoid noisy water texture.

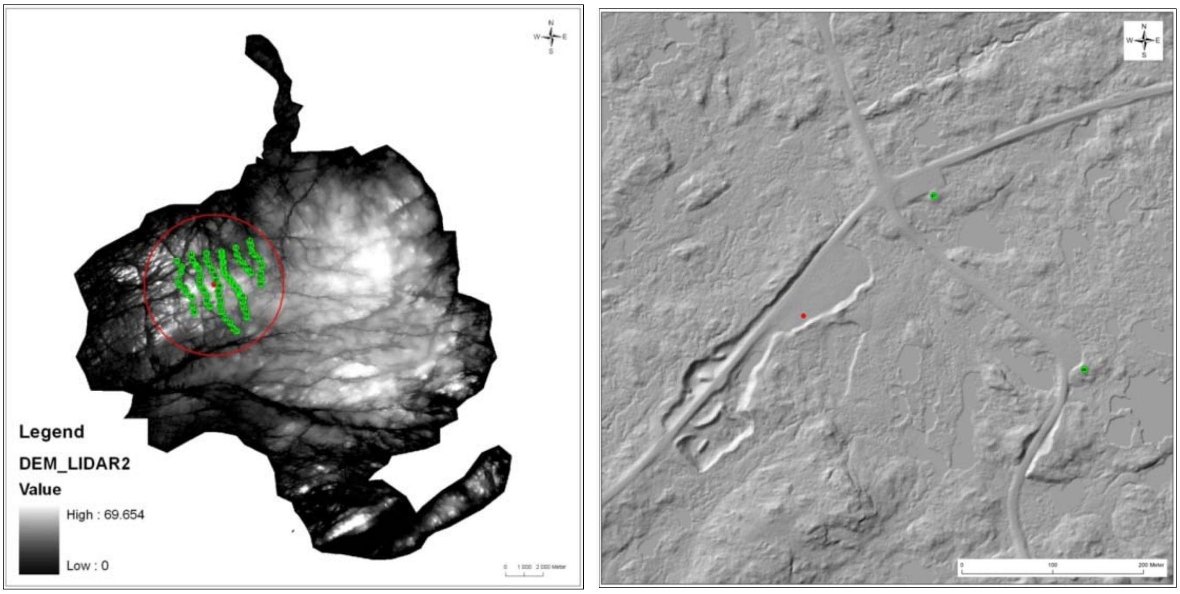


Figure 70. *DTM1 (the current radar location is marked with a red dot). The resolution of this terrain model is 1x1 meters enabling very high precision line of sight studies and land surface clutter modelling.*

9.5 Line-of-sight studies

To assist finding optimal radar locations within the SWPP we developed a line-of-sight model in ArcGIS 9.3 (**Figure 71** and **72**). An optimal radar location is where the radar sees little ground clutter, while maintaining a good, unobstructed view to the area of interest. These are often conflicting requirements and usually a compromise has to be found. The purpose of the modelling was therefore, for any given specific radar location, to identify areas where the surface will be visible from the radar, and create viewsheds of the radar at different altitudes to find the areas in the coverage which will be shadowed by terrain. In this way a theoretical evaluation of new sites can be performed, and the best alternative chosen, without having to move the radar equipment and perform live tests.

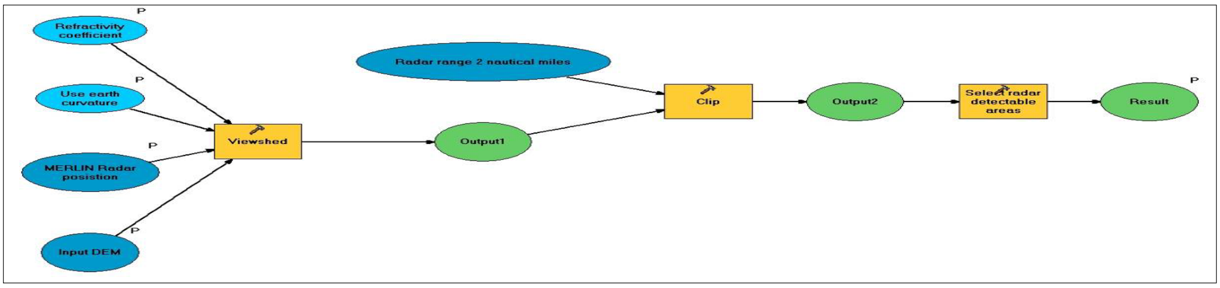


Figure 71. *Line-of-sight model applied on DTM1.The model is developed to* assist finding optimal radar locations within the SWPP.

The line-of-sight studies were performed within two nautical miles (the set range of the MERLIN horizontal surveillance radar). The radar antenna height was set to be five meters above ground level. Vertical view angle was set to 180 degrees and horizontal view angle was set to 360 degrees. Default earth curvature corrections were used together with a refractivity coefficient at 1,003. Viewshed analysis were performed at different altitude intervals (meters above ground) and combined into a line-of-sight map describing the estimated radar line of sight coverage at different altitudes from a specific radar location.

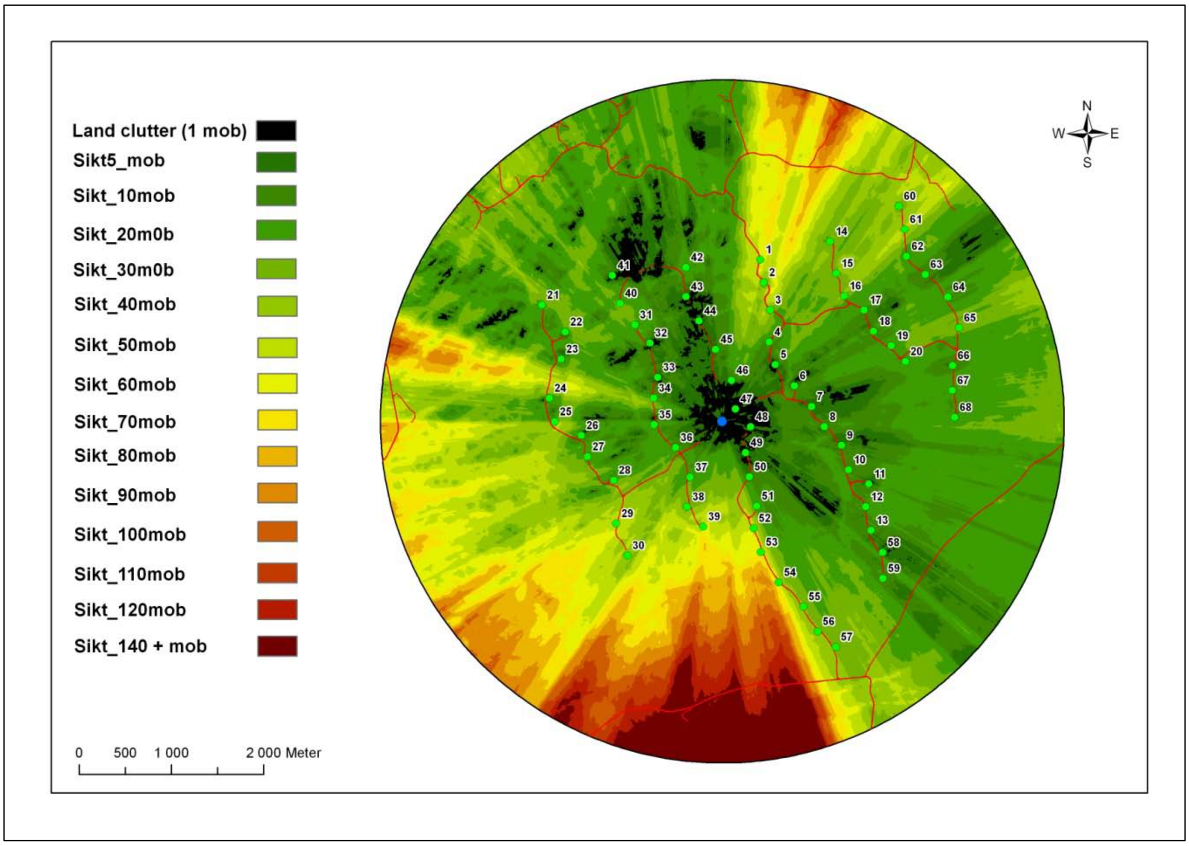


Figure 72. *Line-of-sight studies based on DTM1. The colours indicate the minimum height above ground for a target to be visible from the radar at the given position (blue dot).*

The refractivity coefficient used in the model is for infrared light. The refraction at radar frequencies is slightly higher, but at this range scale it is considered to be an insignificant difference. As a coarse compensation for the combined effect of refraction and diffraction of the radar rays over the coverage area, areas in which targets up to 1 m above the ground will be visible, are defined and marked as ground clutter areas. These portions of the coverage are marked in black in the figure above. With this adjustment, the shape and size of theoretically calculated clutter areas were found to correspond very well with the actual recorded ground clutter in the radar.

9.6 Land surface clutter modelling

In addition to the line-of-sight studies (areas of ground clutter and visibility at different altitudes), there was a need to model also the reflectivity properties of the land surface inside the clutter areas.

The input data in the land surface clutter model is the DTM1, detailed land cover vector data from AR5 (The Norwegian Forest and Landscape institute), the actual radar location (XYZ) and a range of two nautical miles.

Aspect and slope are derived from the DTM1. XYZ-coordinates; aspect and slope are then averaged for each radar resolution cell using zonal statistics tools in ArcGIS. Antenna distance vectors (from radar location to every radar resolution cell) and normal vectors (on each radar resolution cell) are calculated from the averaged GRID`s. Grazing angles are calculated from the antenna distance and normal vectors. From viewshed analysis land clutter areas are indentified (areas that are visible from the radar antenna). All negative grazing angles facing away from the radar are removed. Grazing angles facing against the radar inside the surface clutter areas are finally extracted for further calculation of land surface reflectivity.

The land surface reflectivity, $\boldsymbol{\sigma^0}$, is estimated using the simple "constant gamma" model $\boldsymbol{\sigma^0 = \gamma \sin(\psi)}$, where $\boldsymbol{\gamma}$ describes the scattering effectiveness of the different land clutter types, and $\boldsymbol{\psi}$ is the grazing angle at the land surface in each radar resolution cell. The model output is the land surface reflectivity of each resolution cell, which multiplied with the cell area, gives the resolution cell Radar Cross Section (RCS), and hence the land clutter echo level. The model steps are illustrated in **Figure 73**.

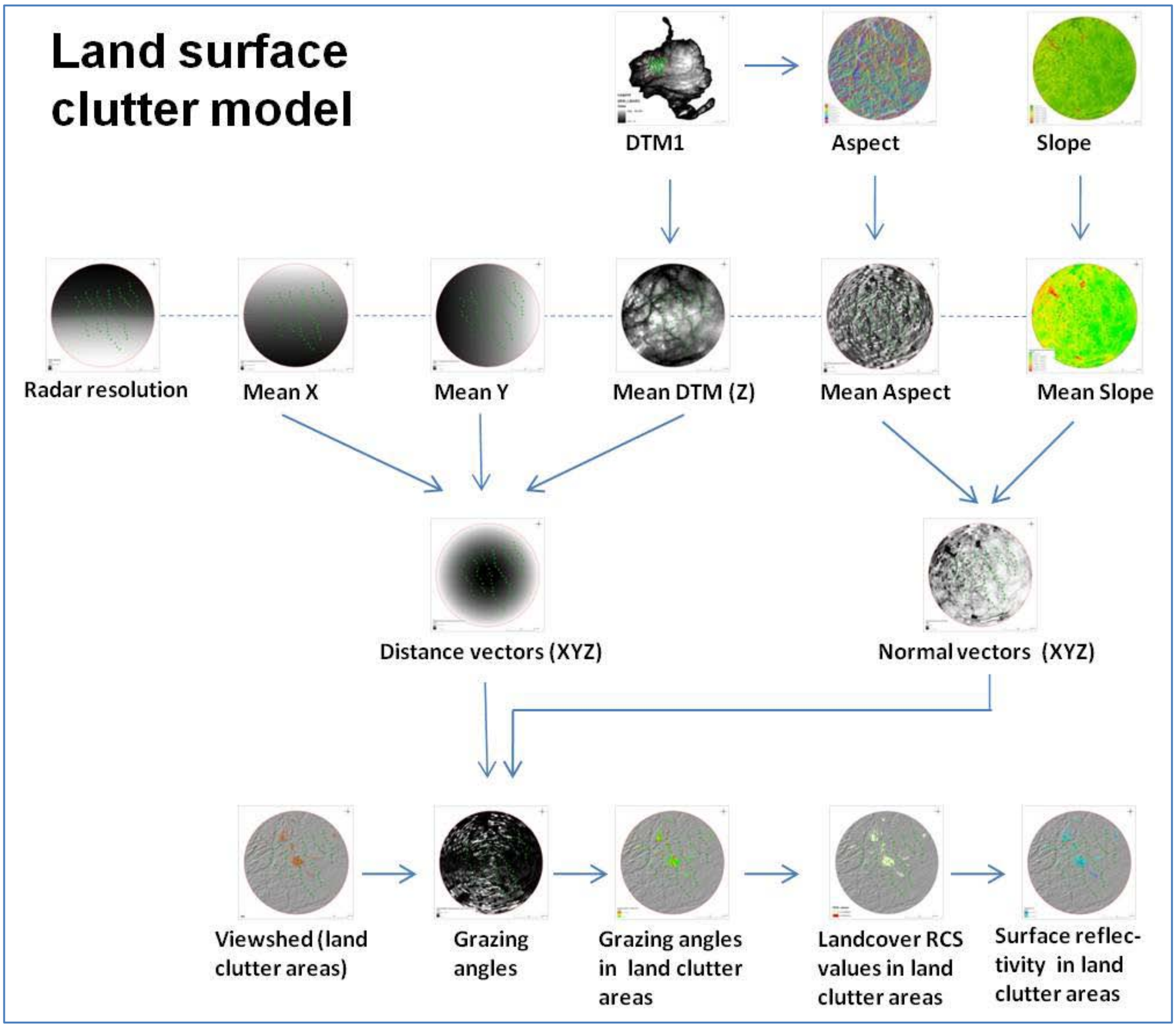


Figure 73. *Illustration of the land surface clutter model steps. The model is developed to identify surface reflectivity properties inside the land clutter areas.*

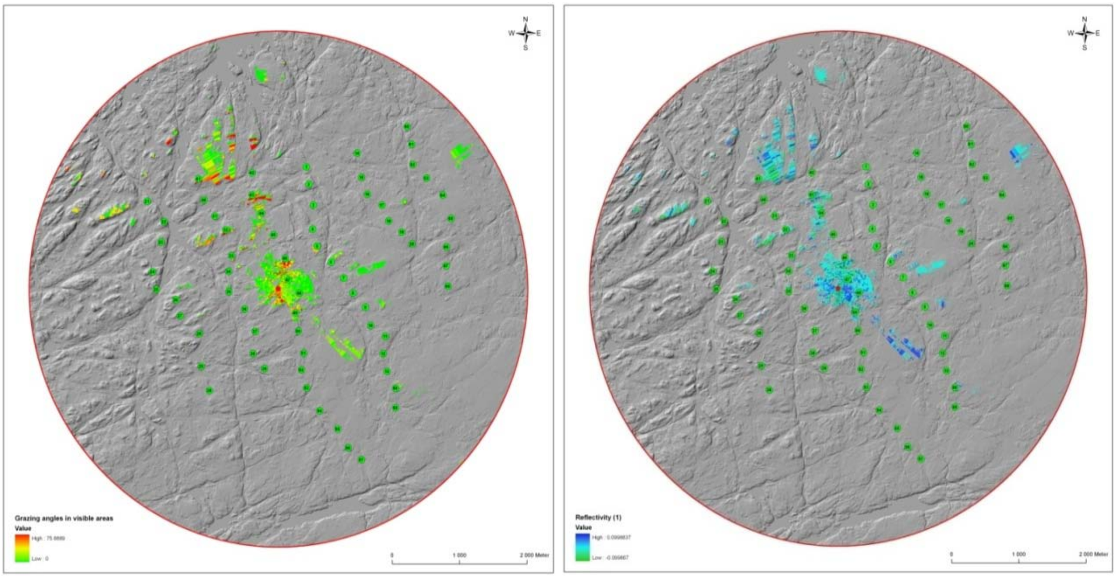


Figure 74. *Line-of-sight studies based on DTM1. The left part of the figure illustrates the modelled grazing angles (from green to red) of the terrain inside the land clutter mask. The right part of the figure illustrates the modelled reflectivity values (from green to blue) inside the land clutter mask.*

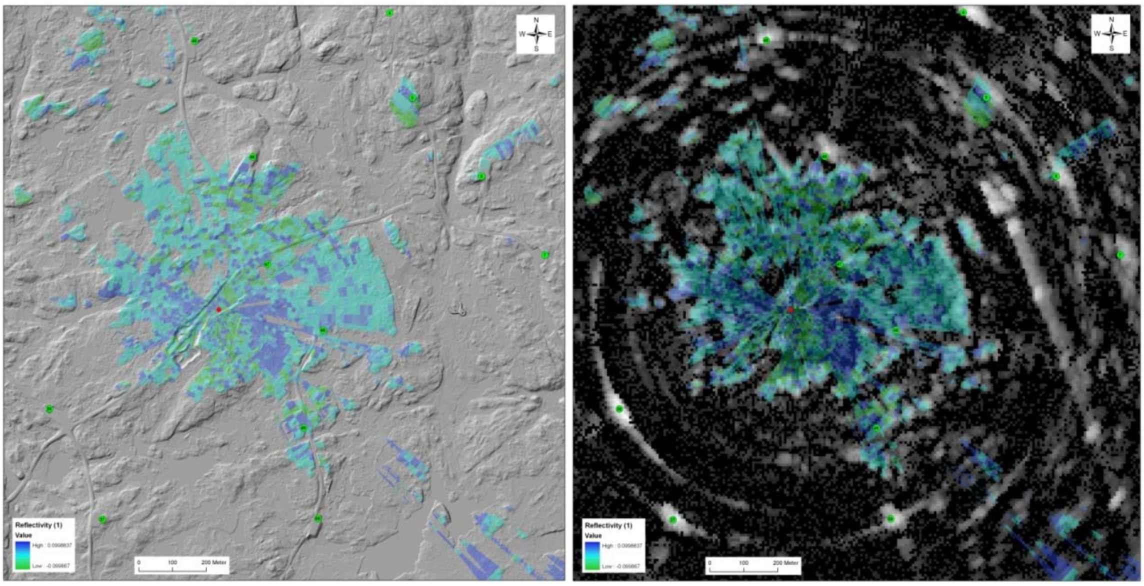


Figure 75. *Comparisons between modelled land surface clutter and the static clutter map processed by the MERLIN processor. The left part of the figure illustrates the modelled reflectivity values (from green to blue) inside the land clutter mask. The right part of the figure illustrates the reflectivity values (from green to blue) overlayed with the white clutter areas identified by the MERLIN- processor*.

The land surface clutter model correlates relatively well with the radar clutter picture even though is seems to be a slightly underestimation. This can be related to potential errors in the DTM1 and the fact that the model only includes a very simple method to account for any refractivity or diffraction effects. However, the model is easy to perform and very useful in terms of finding good radar locations which sees a minimum of ground clutter and at the same time has the required coverage.

In addition to ground clutter, inside a wind park, the wind turbines themselves are sources of radar interference of a quite particular kind (see **Figure 76**).

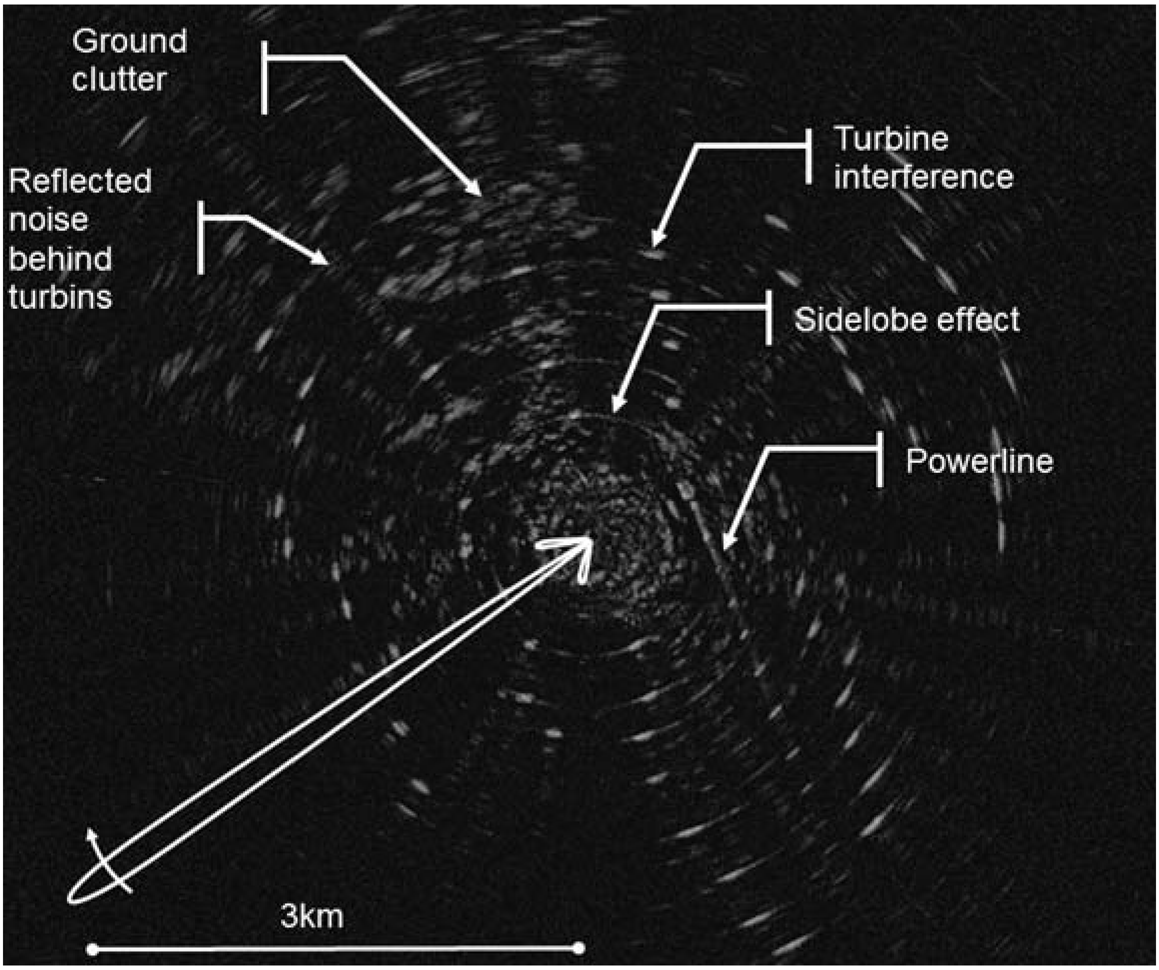


Figure 76. *Radar-induced clutter in the Smøla wind-power plant area*.

Here we can see that each turbine is a large echo which also is strong enough to leak through the sidelobes of the antenna causing a ring like clutter trace to appear. But the most severe clutter from the wind turbines is the stripe of ground clutter behind each turbine. These echoes are caused by energy which is reflected of the nacelle and blades towards the ground behind the turbine, and takes the same way back to the radar. This clutter varies with the angle of the nacelle (i.e. wind direction) and is seen to flicker with the position of the turbine blades. This complex temporal variation makes it particularly difficult to handle in the automatic processing.

The ground clutter model does not include clutter interference from the turbines. A simple viewshed approach has been performed in order to identify the clutter areas behind the turbines (see **Figure 77**).

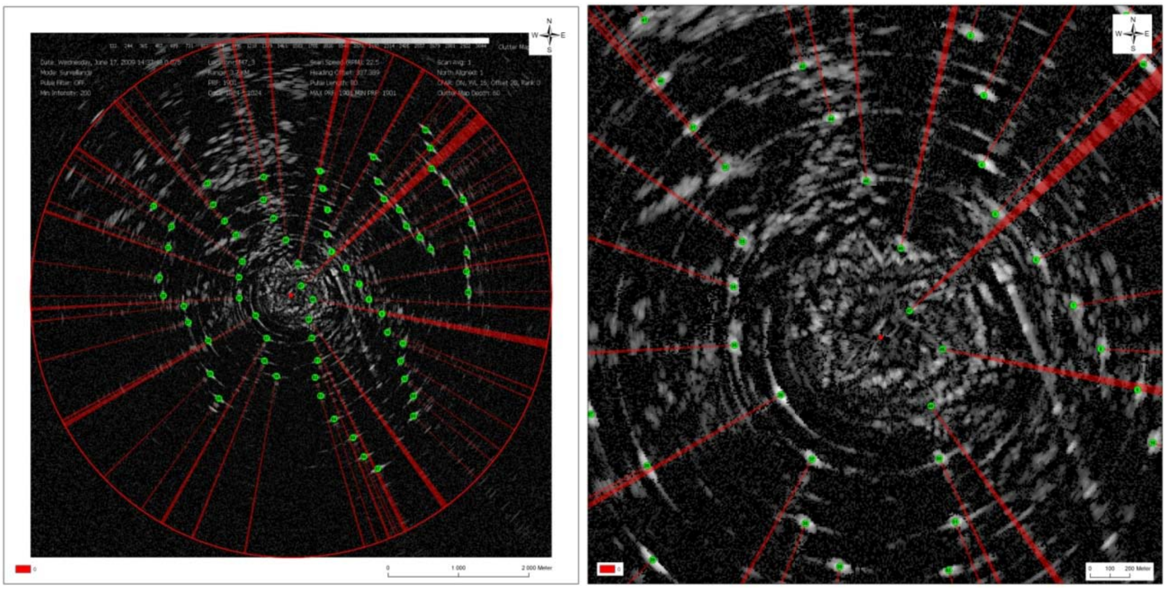


Figure 77 *A simple viewshed approach for modelling of shadow areas behind turbines. This approach is developed to model shadowed areas behind each turbine from a given radar location.*

The modelled land surface clutter areas are finally imported into the radar detection database as a clutter mask. The clutter mask is used to help interpret the radar data automatically detected and recorded in the data base.

9.7 Preliminary conclusions and remaining questions

Conclusions:

- Using GIS-modelling and high precision elevation data to perform line-of-sight studies and ground-clutter modelling have made important contributions in order to optimize the radar localisation and tagging of potential false tracks inside the theoretical land clutter areas stored in the MERLIN Horizontal database. The models are flexible and easy to perform. The land clutter mask is currently implemented in the MERLIN Horizontal database. Every track identified inside the land clutter mask is automatically tagged as potential false tracks.
- The land clutter seems to correlate well with the clutter areas identified with the static clutter map detected by MERLIN.

Remaining questions:

- The modelled reflectivity properties of the terrain still remain to be statistically compared with the static clutter map detected by MERLIN. A remaining question is therefore how to extract land clutter reflectivity values from the MERLIN processor.
- A rather complex remaining question is how to model the turbine interference and the severe clutter reflected from the stripe of ground clutter behind each turbine. These echoes are caused by energy which is reflected of the nacelle and blades towards the ground behind the turbine, and takes the same way back to the radar. This clutter varies with the angle of the nacelle (i.e. wind direction) and is seen to flicker with the position of the turbine blades. This complex temporal variation makes it particularly difficult to handle in the automatic processing.
- We have not yet been able to model the radar detected bird tracks in 3D as originally planned due to the fact that MERLIN is not a 3D radar. However a number of WTEs on Smøla will be equipped with 3D GPS in 2011 and we hope to be able to correlate some of these 3D GPS bird tracks with the MERLIN horizontal database in order to study and visualize the detected bird activities in 3D as originally planned.

10 Summary, preliminary conclusions and remaining questions

The BirdWind project (2007-2010) is now concluded. This report summarises the main findings. Several scientific papers are in the process of preparation for publication in international peer review journals, this report only provides a brief overview. The main project objective has been to study species-, site- and season-specific bird mortality and how it is influenced by environmental and technical factors. The obtained knowledge-base could improve the design of future pre- and post construction EIAs in connection with wind power-plant constructions. To reach these goals several work packages and sub-projects have focused on behavioural and response studies at individual and population levels, for selected model species. The white-tailed eagle (WTA) has been a focal species during the studies, as several fatalities were recorded in connection with the Smøla Wind-Power Plant (SWPP) even before the project started and the SWPP has been the main arena for the fieldwork carried out. Modelling the WTE collision risk and modelling the WTE population dynamics were important elements of the project activities. The development of methodologies and technical tools for data collection and mitigating measures has also been an important part of the project.

For practical convenience the project was divided into eight subtask focusing on 1) bird mortality, 2) willow ptarmigan, 3) breeding waders and smaller passerines, 4) white-tailed eagle, 5) bird radar, 6) mitigating technology, 7) data flow and storage systems and 8) GIS, visualization and terrain modelling.

Mortality. The main objective of this subtask has been to document wind-turbine induced bird mortality, including searches for dead birds and bias testing, identifying species-specific factors triggering high collision risk, and possible causes of death and estimating species- specific collision rates. Among the important conclusions is that by using especially trained dogs during the searches for dead birds around the wind turbines, search efficiency and accuracy is significantly increased. Bias testing has revealed that dog search efficiency decreases with distance from the turbines. These data enable correction estimates for dead birds at different distances from the turbines. Dead birds are scavenged by several species; scavenger removal bias varies with season and carcass appearance. The only possibly significant search bias with regard to the white-tailed eagle is the potential for underestimates due to crippling, i.e. birds surviving a collision and moving outside the search area before dying.

Since 2005 39 white-tailed eagles have been recorded as collision victims, on average 7.8 eagles each year, or 0.11 WTE/turbine/year. Of the eagle 28 (72%) have been found during March-May and 7 (18%) in the autumn. Their age distribution was 21 (54%) adults, 11 (28%) subadults, and 7 (18%) juveniles. Eleven (28%) of the white-tailed eagle victims were found close to 5 turbines in the northwest part of the wind-power plant area (between turbine number 21 and 26).

The most numerous victim was the willow ptarmigan. 74 dead birds have been found within the wind power-plant area. This includes birds found dead during the regular turbine-related searches (more than 50), radio-tagged birds found dead after they ceased to move, and birds found by occasion. Between 10-15 specimen were found each year, the majority in March-June (42; 57%), but also in November-January (20; 27%). About half the willow ptarmigan victims have been located within 50 m of the turbine base. Of other species 65 specimen of at least 25 species have been identified as collision victims, between 12 and 15 annually. Most common are the common snipe, golden plover and hooded crow.

To learn more about seasonal-specific scavenger bias additional test experiments should be performed to increase the accuracy of total victim number estimates. For some species it is necessary to get data on mortality caused by other factors than wind turbines. This may be achieved by conducting seasonal searches in control areas outside the wind-power plant area.

Willow ptarmigan. The main objectives of this subtask have been to study direct and indirect effects of wind turbines on willow ptarmigan behaviour, habitat selection, reproduction and survival in areas where wind-power plants are established or planned. Although there is some variation in density of the August population of willow ptarmigan, there was no consistent difference between the wind-power plant area on Smøla and the nearby control area. Compared to other willow ptarmigan populations, chick production is reasonably good, and no difference was found between the SWPP area and the control area. The willow ptarmigan to a great extent uses suitable habitats in the SWPP area, and no evident avoidance behaviour is observed. Those living in the SWPP area a have strong site tenacity and movements outside the SWPP area only happen during periods with deep snow cover which make food inaccessible within the SWPP. The annual mortality of radio-tagged birds is much higher than in inland willow ptarmigan populations (>70% vs. 50%), and the mortality pattern is different from the pattern found in inland populations. Heavy winter mortality of radio-tagged birds seems to be mainly caused by natural mortality from migrating and wintering raptors.

This study has given new and unique information about this island population of the Smøla willow ptarmigan. However, there are still many questions unanswered. With respect to the special concern about possible negative effects of wind-power plants we need to answer questions regarding the population effect of natural mortality compared to turbine-induced mortality. To improve estimates of the extent of turbine-induced mortality, better estimates of scavenging rates of dead willow ptarmigan is required. A particularly challenging task will be to sort out possible mitigating measures to reduce the collision hazard for willow ptarmigan.

Breeding waders and smaller passerines. The main objectives of this subtask were to survey the breeding populations of waders and small passerines in relation to wind turbines and assess any evidence for effects on bird distribution in relation to wind turbines. The field work was carried out on Smøla in 2007, in a planned wind-power plant area on Andmyran in 2008, and in connection to a planned extension of the Hitra wind-power plant in 2009. There is evidence that several species of small birds and waders avoid the vicinity of wind turbines on Smøla. All of these species are however common on a regional, national, and world scale and none of them are listed in the 2010 revision of the Norwegian Red List. However, if this behaviour is representative of rarer small birds and waders it may be significant for their populations if wind-power plants are built on or close to concentrations of such species, either in the breeding season or at other times. The precautionary principle would suggest avoiding building wind power installations in such areas, which will probably be rare in Norway with many alternative sites available. Study of effects on such rarer birds (e.g. ruff) may be useful, if practical to achieve. The proposed wind-power development at Andmyran (approved but not yet constructed) would be very suitable for a BACI (before and after control impact approach) study of effects on small birds and waders, and other species. Such studies are currently rare and offer better quality data than other approaches.

White-tailed eagle – GPS satellite telemetry. The main objective of this subtask was to use satellite telemetry to acquire information on white-tailed eagle movements and data for collision risk assessments. GPS satellite telemetry on juvenile white-tailed eagles has provided detailed insight into their behaviour within and outside the wind-power plant. A probability analysis using GIS which was based on GPS-locations showed that collision risk is highest during their first autumn and during spring in their second year. This coincides in time with the dates of the casualties of satellite-tagged birds. A Kaplan-Meier survival analysis indicated that the cumulative survival of the satellite-tagged juveniles during their first three years of life was reduced by 10% due to wind-power plant related casualties. Collision risk modelling has shown that white-tailed eagles are most prone to collide during the spring period. Also the developed Brownian bridge methodology not only provides insight into temporal effects, but it enables also the delineation of specific areas or specific turbines with increased risk. The juveniles show a cyclic movement pattern, involving dispersal during summer, mainly to the north, and a return movement to the area they were born in the spring, with a new movement away during the next spring. Over years, they seem to be more and more attached to their region of birth. Females move further than males. Their movements along the coast involves visiting many potential future sites for wind-power development, which illustrates the possible nation-wide scale of cumulative effects; any young white-tailed eagle born along the coast has a potential chance of entering any planned and existing wind-power plant along the Norwegian coast. Two large night-roosts close to the turbines in the north-western part of the Smøla wind-power plant indicate a connection between the use of these and the high collision rates at these turbines.

Our findings show that the majority of the white-tailed eagles killed by wind turbines on Smøla are adult birds. A priority should be to trap territorial breeding birds within and close to the wind-power plant to reveal their detailed movement patters within the wind-power plant in order to assess their collision risk. Many of the satellite-tagged birds still survive wearing active GPS-tags, and it should be a priority to follow them further throughout their lives to gain more knowledge of their movement patterns and survival. Central to collision-risk modelling is the possible effect of avoidance behaviour. This may include both displacement effects (i.e. where the wind-power plant is no longer perceived as habitat) and behavioural responses at different spatial scales (avoidance of the wind-power plant, a specific turbine or last-second avoidance of moving rotor blades). This should receive more focus in the future.

White-tailed eagle – DNA. The main objective of this subtask has been to estimate adult mortality among breeders in, or close to, the SWPP based on DNA-analyses of moulted feathers from adult birds and plucked feathers from chicks at the nesting sites. DNA sampling of moulted feathers has proven to be a cost-effective method for estimating the number of active territories within the SWPP. A simple survey of nesting sites may overestimate the number of breeding pairs; in our case by approximately 15%. This has important implications to the evaluation of the vulnerability of any white-tailed eagle population. Development and optimization of the DNA methods used herein have given us invaluable experience, which makes it easier to address similar questions also for other birds of prey. Preliminary results indicate that the SWPP constitutes an important mortality factor for the white-tailed eagle population on Smøla, accounting for more than 50 % of the detectable adult mortality. In particular, birds breeding within or close to the wind-power plant seem to be especially vulnerable to wind power related mortality. A relatively large proportion of the adult eagles that have been found dead in the wind-power plant are not represented in our database of breeding pairs. This suggests that a certain proportion of adult eagles in the population do not defend their own territory, and are referred to herein as floaters.

Several remaining questions regarding the white-tailed eagle on Smøla may be answered using DNA-analyses. The proportion of non-territorial adult birds or floaters in the population can be estimated by simulating the expected number of matches given the representation of known breeding birds in our database of adult eagles. The database, from which we monitor turnover and the origin of dead eagles, allows us to identify breeding territories that are particularly vulnerable to wind-turbine induced mortality. Such knowledge is important for implementation of appropriate mitigation efforts that potentially can reduce the extra mortality imposed by the wind-power plant. During the project period we have generated a five year time series, from which adult mortality in the population can be formally estimated. However, the number of dead birds and matches to our database is still relatively low. Therefore, for more robust estimation of adult mortality, the time series should be extended. This will allow us to model how the wind-power related mortality affects the population growth rate. In addition, we recommend that a similar time series is generated for a control population which is not affected by wind power development. This will enable us to separate the wind power related mortality from the background mortality in a natural WTE population.

White-tailed eagle – breeding success. The main objective of this subtask has been to monitor possible changes in the white-tailed eagle breeding population on Smøla caused by the development of the wind-power plant, and study whether this power plant has any short- or long-term effect on the eagles' reproduction and breeding success. So far our conclusion is that the overall population on Smøla is stable. The decrease of the population inside the wind-power plant area is due to mortality and displacement. The number of young eagles born on Smøla overall increased throughout the study period (2002-2010), as did the reproductive success. However, the number of young born within the SWPP area decreased, as did the reproductive rate. The data derived from the DNA-analyses was a very, increasing the accuracy of the data significantly. Traditional methods overestimated population size by 10-15% compared to the DNA methods. The WTE-case on Smøla demonstrates the importance of BACI (before-after-control-impact) when population trends are to be studied.

The main remaining questions regarding the white-tailed eagle on Smøla are connected to the analysis of adult mortality/turnover rates in the population based on DNA monitoring (which has already started, and will be finished in the spring 2011). The population model, including the total size, age-structure and turnover rate of the Smøla population based on the DNA-findings will be finalised in 2011. Finally we will model the long-term white-tailed eagle population effects of the SWPP-induced mortality (planned finished 2012 according to the PhD plan for Espen Lie Dahl).

White-tailed eagle – necropsy. The main objective of this subtask was to identify the causes of death based on necropsies on dead white-tailed eagles recorded in connection with turbines in the SWPP, and identify characteristics of lethal wind-turbine imposed injuries. Overall the x-ray pictures show a pattern of violent impacts inflicting massive damage to the skeleton, with a broad spectrum of fracture, although some specimens had only minor damages. Several birds had one wing cut off, but the majority had multiple fractures in different parts of their bodies. The findings in our survey show a picture where the lesions are complex and spread rather evenly on the skeletons. The fracture pattern could be compared to that seen on animals involved in traffic accidents. The number of fractures in a considerable number of the specimens is much higher than found in bird carcasses obtained elsewhere. A great number of bones had many splintering fractures with sharp edges. It is not possible to point at other causes than wind turbine blades for this excessive and sudden application of force to the bodies.

White-tailed eagle - behaviour inside and outside the wind-power plant area. The main objective of this subtask was to observe the WTE behaviour inside the wind-power plant area and in an adjacent control area, to collect data on possible behavioural differences as a response to the wind-power plant. The overall conclusion is that white-tailed eagles on Smøla do not seem to respond by modifying their flight behaviour to the wind-power plant. This may explain the high number of killed individuals in the wind-power plant. The recorded behavioural differences between adults and subadults, may explain the age difference among the individuals found killed inside the wind-power plant area. A higher number of adults than subadults found killed can be due to behavioural differences, such as spending more time on social behaviour and flying back and forth between nests and feeding areas. Furthermore, if such behaviour increases the risk of collisions for adult individuals, this can contribute to explain the higher number of recorded subadults inside the wind-power plant area found in this study. This should be carefully considered when looking at the possible long-term effects of the wind-power plant on the white-tailed eagle population on Smøla. Assuming that the overall observations are representative, it clearly imposes constraints on mitigating measures to decrease the white-tailed eagle collision hazard. The results underline the importance of conducting thorough pre-construction studies to identify wind-power plant siting with low densities of species vulnerable to collision. A more accurate prediction of high-hazard collision periods based on environmental variables like air temperature, wind and precipitation triggering high flight activity in March-May, would make it possible to advise the wind-power plant operator when to close down the wind-power plant – or single turbines - during high-risk conditions to reduce eagle mortality

Bird radar. The study of behavioural responses of birds to man-made structures like the wind farm at Smøla, requires ways to observe and document the movement of birds in the area of interest. Human visual observation remain an indispensable prerequisite and a key method, but a dedicated radar system is a powerful instrument which greatly extends the observation capability, both in terms of observation period, and the size of the surveillance area. E.g. the radar can be set to cover the relatively large area of a wind-power plant, and operated 24 hours a day all year round at all types of weather conditions, which is a task impossible to achieve with the use of human observers alone. At the same time the radar offers means for continuously recording of the radar picture which provides documentation of the activities in the surveillance area.

However, the use of radar for this purpose has site- and system-specific limitations that are important to be aware of when the data output is evaluated. An important task in the project has therefore been to start using radar as an instrument to monitor and record bird behaviour in the vicinity of large wind turbines. To our knowledge, it is the first time radar has been deployed for this kind of research in Norway. Important objectives of this work package have been to experiment and develop the necessary methods, and gain general experience using radar as a research instrument. One of the main conclusions is that avian radar is not a tool that can be utilized without proper knowledge on both the technological, methodological and biological aspects concerned. We have developed various practical methods/tools to aid radar personnel to ease localisation, set-up and calibration of radar equipment, as well as provide protocols to handle data analysis. Then, avian radar may provide many new insights into bird behaviour, not in the least connected to possible effects of wind-power development – both in the pre- and post-construction phase. Analyses from Smøla visualize, for example, fluxes of spring/autumn migration, species-specific bird behaviour; possible collision tracks and provides improved ways to analyze avoidance behaviour at a fine spatial scale.

Important remaining questions relate to the fact that an avian radar can provide near real-time information on bird activity. This may be used to identify periods and/or areas with increased risk for collisions. What remains to be done is to develop a collision risk model based on these data; rendering insight into higher levels of bird activity at rotor-swept height at each turbine at any given time. If this model proves to have predictive power, when verifying with recorded casualties, it may potentially be utilized to warn wind-power plant personnel to idle turbines. The data collected from April 2008, and onwards, needs to be analyzed with respect to correlates with time-of-year, time-of-day and especially weather (e.g. wind speed and direction, visibility, etc.). Comparing these patterns with correlates between recorded casualties and for example weather parameters (especially wind speed) may form the basis to define mitigation measures such as idling turbines in given pre-defined situations. The MERLIN avian radar employed at the Smøla wind-power plant only provides insight into local patterns of bird activity. Especially for wind-power plants along the Norwegian coast, improved knowledge on large-scale migration routes will be important. Utilizing the large-scale 3D radar systems, employed by the Royal Norwegian Air Force and the Norwegian Meteorological Institute, to extract birds from their signals will be important. Currently our knowledge on bird migration routes is largely based on recoveries of ring-marked birds.

Methods and technology to mitigate bird mortality in the SWPP. The overall objective of this subtask has been to assess the current knowledge on the effectiveness of tools and technology that may reduce bird mortality in connection to wind-power plants and - based on the review conclusions – suggest concrete actions to mitigate the WTE mortality within the SWPP. One of the main conclusions is that - although the subproject has not met its initial expectations - the findings and the increased understanding of the complexity provides a basis for further work on these challenges at a later stage. Progress on developing mitigating measures to reduce the collision hazards require increased species-specific knowledge of how the behaviour is determined by their vision's (including colour and movement sensibility), and at what distance their visual stimuli are triggered. Without this knowledge it is difficult to assess how e.g. the WTE view and understand the movements of the rotor blades and other wind-turbine associated structures. Increased knowledge on how birds are using their biomechanics and aerodynamic skills, to cope with the turbulence and vortices in the vicinity of the wind turbines is also needed.

To modify a wind turbine towards a more bird-friendly design requires knowledge on how the rotor blade speed and design modify the generated turbulence, and how these parameters are modified by local topography and wind conditions. A key issue for future research will be whether wind turbine-related mortality is affected by the speed of the rotor blades, as well as whether the flight path of birds are affected by the turbine-generated turbulence in a way that may be predicted. A next step will be to assess whether this is caused by the bird not perceiving the rotor blades (motion smear), whether it is trapped in a turbulence outside its control due to body biomechanical constraints and thus being dragged towards the rotor blades, or whether the turbulence creates vortices and air pockets with increased/lowered air pressure obstruct lift resulting in loss of control. By developing a functional camera system in the SWPP it should be possible to record data that could answer remaining questions on how the WTE and willow ptarmigan behave when close to the turbines. Together with increased knowledge on their vision and biomechanics, possible changes in flight paths may be analysed and connected to perception parameters and local wind conditions (e.g. distance when the birds react, how fast they react, avoidance distance and avoidance behaviour). This requires an improved camera technology together with theoretical approaches regarding the importance of bird vision and aerodynamic abilities.

Data flow and storage systems. The main objective of this subtask has been to develop a comprehensive technical infrastructure for efficient data flow, storage, retrieval, management and analytical use of bird-detection data from the installed camera systems close to turbine number 43 and the MERLIN radar and applied satellite telemetry. The avian radar system generates huge amounts of raw data when there is much activity inside and around the SWPP. The raw data are processed in place and this result in two new Microsoft Access database files each day for the vertical and horizontal radar systems. Each night at 2 AM, a job is invoked, which transfers the files to the central file server located at NINA HQ in Trondheim. Then another job grabs these files, processes them, and populates the central database server with the new entries.

The 6 cameras positioned around wind turbine no 43 have generated huge amounts of data, as each camera records 6 frames per second (fps) when movement is detected nearby. Recorded data is transferred daily to NINA HQ, and stored in the connected storage solution. We have special viewing software to investigate the recorded images when they are transferred to the storage system. The avian radar and the camera systems are connected via radio links, which also provides the Internet gateway. A local Internet Service Provider (NEAS) provides the Internet connection from the radar/camera systems (10 Mbit/s). Between Smøla and Trondheim we have a site-to-site VPN tunnel for secure data transfer.

The storage system consists of an HP ProLiant server with two SAN-attached disk enclosures with a total capacity of 8 TB. The storage server is running Microsoft Windows Server 2003 Storage Edition and EMC DiskXtender for Windows which offers highly scalable data management to enable a tiered storage strategy. EMC DiskXtender for Windows transparently migrates inactive or infrequently accessed files to a HP StorageWorks MSL4048 Tape Library which offers up to 76.8 TB of storage, without changing the user's view or access. The data flow infrastructure was established in 2008, and has been working as intended. However, we have seen the need to “tune” the data flow, and also to split the data into more fragmented databases and file systems to gain better performance when querying against the most interesting parts of the data. The “tracks” database is growing very fast (several hundreds of millions records) and with these amounts of data, filtering and splitting of the data is essential.

GIS, visualization and terrain modelling. The main objective of this subtask has been to visualize the bird real activity patterns in 3D, establish a methodology and model possible conflict areas between birds and wind-power plants. Most of the efforts in this subproject have focused on terrain modelling, line-of-sight studies and ground-clutter modelling. Using GIS-modelling and high precision elevation data to perform line-of-sight studies and ground-clutter modelling have made important contributions, in order to optimize the radar localisation and tagging of potential false tracks inside the theoretical land clutter areas stored in the MERLIN Horizontal database. The models are flexible and easy to perform. The land clutter mask is currently implemented in the MERLIN Horizontal database. Every track identified inside the land clutter mask is automatically tagged as a potential false track. The land clutter seems to correlate well with the clutter areas identified with the static clutter map detected by MERLIN.

However, there are some remaining questions, e.g. the modelled reflectivity properties of the terrain remain to be statistically compared with the static clutter map detected by MERLIN. A remaining question is therefore how to extract land clutter reflectivity values from the MERLIN processor. Another rather complex unanswered question is how to model the turbine interference and the severe clutter reflected from the stripe of ground clutter behind each turbine. These echoes are caused by energy which is reflected by the nacelle and blades towards the ground behind the turbine, and takes the same way back to the radar. This clutter varies with the angle of the nacelle (i.e. wind direction) and is seen to flicker with the position of the turbine blades. This complex temporal variation makes it particularly difficult to handle in the automatic processing. Moreover, we have not yet been able to model the radar-detected bird tracks in 3D as originally planned due to the fact that MERLIN is not a 3D radar. However, if we succeed in equipping some WTEs on Smøla with 3D GPS in 2011, this open up for correlating some of these 3D GPS bird tracks with the MERLIN horizontal database in order to study and visualize the detected bird activities in 3D as originally planned.

11 Sammendrag, foreløpige konklusjoner og ubesvarte spørmål

BirdWind prosjektet (2007-2010) er nå avsluttet, og denne rapporten inneholder en kortfattet oppsummering av de viktigste resultatene. Flere vitenskapelige artikler er i ferd med og ferdigstilles for publisering i internasjonale, vitenskapelige tidsskrift. Hovedmålsettingen med prosjektet har vært å studere arts-, steds og årstidsspesifikk dødelighet hos fugl samt identifisere sårbare arter og faktorer det bør legges vekt på for å bedre grunnlaget for for- og etterundersøkelser når nye vindkraftverk skal etableres. For å nå disse målsettingene har de ulike arbeidspakkene i prosjektet fokusert på atferds- og responsstudier både på individ- og bestandsnivå hos utvalgte modellarter. Havørn har stått sentralt i prosjektet ettersom flere drepte ørner ble rapportert fra vindkraftverket på Smøla allerede før prosjektet ble igangsatt, og det var derfor naturlig at det meste av studiene ble lagt hit. Modellering av kollisjonsrisiko hos havørn, samt utarbeidelse av en bestandsmodell for havørn har følgelig vært en viktig del av arbeidet. Metodeutvikling og utvikling av effektive redskaper for datainnsamling og avbøtende tiltak har også vært spesielt fokusert.

Av praktiske hensyn har prosjektet vært delt inn i åtte underprosjekt som har vært konsentrert om 1) dødelighet hos fugl, 2) smølalirype, 3) hekkende vadefugler og mindre spurvefugl, 4) havørn, 5) fugleradar, 6) teknologi knyttet til avbøtende tiltak, 7) dataflyt og datalagringssystemer, 8) GIS, visualisering og terrengmodellering.

Dødelighet. Hovedmålsettingen med dette delprosjektet har vært å dokumentere vindturbinindusert dødelighet hos fugl, inklusive søk etter døde fugler og testing av feilkilder samt dokumentere artsspesifikke faktorer som medfører økt kollisjonsrisiko og på hvilken måte fuglene blir drept. Dette har i sin tur dannet grunnlag for estimering av artsspesifikke kollisjonsrater. En viktig konklusjon er at ved å benytte hunder som er spesialtrenet til å finne død fugl, så økes søkseffektiviteten og -nøyaktigheten betydelig. Gjennom eksperimentell testing av mulige feilkilder har det vist seg at søkseffektiviteten minsker når avstanden til vindturbinene øker. Dette har gjort det mulig å legge inn avstandsspesifikke korreksjonsfaktorer når den totale dødeligheten skal estimeres. Døde fugler blir ofte funnet og spist av ulike åtseletere, og eksperimenter har vist at forsvinningsraten varierer med årstid og synligheten til kollisjonsofrene. Den eneste mulige feilkilden av en viss betydning når det gjelder havørn antas å være den som er knyttet til at ørner kan ha blitt skadet, men ikke verre enn at de har klart å komme vekk fra søksområdene i vindkraftverket før de har dødd, og derfor ikke blitt funnet (”*crippling bias*”).

Siden 2005 har 39 havørner blitt funnet og identifisert som kollisjonsofre, i gjennomsnitt 7,8 ørner pr. år, eller 0,11 ørner/turbin/år. I alt 28 (72 %) er funnet i perioden mars-mai og 7 (18 %) om høsten. Til sammen 21 (54 %) av ørnene har vært voksne fugler, dvs. at de har vært så gamle at de kan reprodusere. Elleve (28 %) av ørnene har vært subadulte (dvs. at de ikke har vært i reproduserbar alder) og 7 (18 %) har vært ungfugler (opptil ett år). Elleve (28 %) av ørnene er funnet i nærheten av 5 turbiner i den nordvestlige delen av vindkraftverket (mellom turbin nr. 21 og 26).

Den fuglearten det er funne flest individer av under søkene har vært smølalirype. I alt 74 døde ryper har blitt funnet innen området til vindkraftverket. Dette omfatter både individer som er funnet døde i tilknytning til de regulære søkene (mer enn 50 ind.), radiomerkede ryper (dødelighetssendere) som har blitt funnet når de har sluttet å bevege seg, samt tilfeldige funn av døde ryper. Mellom 10 og 15 rype er funnet årlig, de fleste i perioden mars-juni (42; 57 %), men en del også i november-januar (20; 27 %). Omkring halvparten av rypene er blitt funnet innen en radius på 50 m fra turbintårnene. I tillegg har til sammen 65 individer av minst 25 andre arter blitt funnet; mellom 12 og 15 individer hvert år. Flest individer er det funnet av enkeltbekkasin, heilo og kråke.

For ytterligere å bedre grunnlaget for å korrigere for den årstidsspesifikke feilkilden knyttet til åtseletere er det ønskelig med flere felteksperimenter. For noen arter er det også nødvendig å frembringe flere data om andre dødsårsaker enn de som er knyttet til vindturbinene. Dette kan oppnås gjennom å utføre sesongspesifikke søk i kontrollområder utenfor området til vindkraftverket.

Smølalirype. Målsettingen med dette delprosjektet har vært å studere direkte og indirekte effekter av vindturbiner på artens atferd, habitatvalg, reproduksjon og overlevelse i områder hvor det finnes vindkraftverk, eller i områder hvor det er planlagt nye kraftverk. Selv om det er påvist en viss variasjon i bestandstettheten hos ryper i august, er det ikke påvist entydige forskjeller i bestanden innen området til vindkraftverket på Smøla og et kontrollområde i nærheten. Sammenlignet med andre lirypebestander har kyllingproduksjonen vært relativt god, og det er ikke funnet noen forskjell mellom vindkraftverketområdet og kontrollområdet. Rypene benytter i stor utstrekning passende leveområder innenfor vindkraftverkområdet, og det er ikke observert noen klar unnvikelseseffekt. De som lever innenfor området til vindkraftverket viser en høy grad av stedtrohet (”*site tenacity*”) og de beveger seg utenfor området bare når det er dyp snø som dekker vegetasjonen og hindrer dem i å finne mat. Den årlige dødeligheten hos radiomerkede ryper innenfor området til vindkraftverket er mye høyere enn i innlandbestander (>70 % vs. 50 %), og dødelighetsmønsteret er også forskjellig i fra det en finner i innlandet. Høy vinterdødelighet hos de radiomerkede rypene på Smøla synes i stor grad å være forårsaket av omstreifende eller overvintrende rovfugler.

Denne studien har gitt ny og unik informasjon om bestanden av smølalirype på Smøla. Det er imidlertid flere ubesvarte spørsmål. Når det gjelder mulige negative effekter av dødeligheten som skyldes vindturbiner er det bl.a. nødvendig å få svar på effektene av naturlig dødelighet sammenlignet med vindturbinindusert dødelighet. For å klare det er det særlig viktig å få mer detaljerte data om fjerningsraten forårsaket av åtseletere. En særlig utfordrende oppgave er knyttet til å utvikle eventuelle avbøtende tiltak for å hindre/redusere dødelighet hos lirype som følge av vindturbiner.

Hekkende vadere og mindre spurvefugl. Hovedmålsettingen med dette delprosjektet har vært å kartlegge hekkebestanden av vadere og mindre spurvefugl i relasjon til vindkraftverk, og vurdere eventuelle effekter som vindturbiner kan ha på deres forekomst og fordeling i terrenget. I 2007 ble feltarbeidet lagt til Smøla, i 2008 i et område på Andøya (Nordland) hvor det er planlagt bygget et vindkraftverk (Andmyran), og i 2009 på Hitra i tilknytning til planene for en utvidelse av eksisterende vindkraftverk. Det foreligger klare indikasjoner på at flere arter av mindre fugler og vadfugler unngår nærområdene til vindturbinene på Smøla. De artene det dreier seg om er imidlertid vanlige i så vel regional som nasjonal sammenheng, og ingen av dem er med i siste revisjon av den norske rødlista. Det må imidlertid understrekes at hvis dette er en atferdsrespons som er representativ for sjeldnere arter innen disse fuglekategoriene, kan det ha betydning for deres bestander hvis vindkraftverk etableres i områder hvor slike arter hekker eller befinner seg i deler av året. Et føre-var-prinsipp tilsier at det bør unngås å bygge vindkraftverk i slike områder, hvilket skulle være uproblematisk i Norge hvor mange alternative etableringslokaliteter finnes. Studier rettet mot slike sjeldnere arter (for eksempel brushane) kan være nyttig hvis de lar seg gjennomføre i praksis. Det foreslåtte vindkraftverket på Andmyra, hvor konsesjon er gitt, men der bygging ikke er igangsatt, vil være svært egnet for en for- og etterundersøkelse. Slike studier er fortsatt sjeldne og gir en unik mulighet til å få gode data på eventuelle effekter av vindturbiner.

Havørn – telemetri. Hovedmålsettingen med dette delprosjektet har vært å benytte satellittelemetri for å fremskaffe data på bevegelsesmønsteret til havørn i tid og rom, samt for å utarbeide vurderinger av kollisjonsrisiko. Radiosendere med GPS-enhet, der signalene kan fanges opp og videresendes via satellitt, er svært nyttig for å kartlegge forflytninger til fuglearter som beveger seg over store områder. Omkring 60 unge havørner har blitt instrumentert med slike sendere, noe som har gitt detaljert informasjon både om bevegelsene til fuglene innenfor og utenfor vindkraftverket på Smøla. En GIS-basert sannsynlighetsanalyse basert på GPS-posisjoner viste at kollisjonsrisikoen er størst første høsten og om våren i ørnenes andre leveår. Dette sammenfaller i tid med dataene fra radioinstrumenterte fugler som har blitt drept i tilknytning til vindturbinene. En Kaplan-Meier overlevelsesanalyse indikerer at den kumulative overlevelsen hos de radioinstrumenterte ungørnene i deres tre første leveår er redusert med 10 % pga. ulykker i tilknytning til turbinene. Modellering (basert på *Brownian bridge*-metoden) av kollisjonsrisiko har vist at havørnene er mest utsatt for å kollidere om våren. Utvikling av denne metoden gir ikke bare innsikt i tidsspesifikke effekter, men gjør det også mulig å identifisere bestemte områder og bestemte vindturbiner med økt kollisjonsrisiko. De unge havørnene viser et syklisk bevegelsesmønstrer, som involverer at de drar bort fra Smøla om sommeren, hovedsakelig nordover, med retur til fødestedet neste vår, for så igjen å dra ut neste vår. Hunner drar lengre enn hanner. Etter som årene går ser de ut til stadig mer å bli knyttet til områdene de ble født. Bevegelsene langs kysten involverer besøk til mange potensielle, fremtidige lokaliseringssteder for vindkraftverk, noe som illustrerer en potensiell, landsdekkende, kumulativ effekt: Enhver ung havørn som er født ved norskekysten har en potensiell mulighet til å komme i kontakt med hvilket som helst planlagt eller eksisterende vindkraftverk. To store overnattingssteder for havørn i nærheten av vindturbinene i den nordvestlige delen av vindkraftverket på Smøla indikerer en sammenheng mellom bruken av disse og den høye kollisjonsfrekvensen knyttet til disse turbinene.

Dataene fra Smøla viser at de fleste ørnene som er drept i tilknytning til kraftverket er voksne fugler. En videreføring av arbeidet med telemetristudier av havørn bør involvere fangst av voksne fugler i og nær vindkraftverket for i detalj å kartlegge fuglenes bevegelsesmønster innen området til vindkraftverket for å kunne beregne kollisjonsrisikoen. Mange av de radioinstrumenterte ørnene er fremdeles i live og det bør prioriteres å følge opp disse videre for å få mer data og kunnskap om deres bevegelsesmønster og overlevelse. Sentralt i arbeidet med modellering av kollisjonsrisiko står den mulige reduserte kollisjonsrisikoen som følge av eventuelle unnvikelseseffekter. Unnvikelsesatferd kan omfatte både fortrengingseffekt (dvs. hvis området der vindkraftverket er lokalisert ikke blir oppfattet eller foretrukket som leveområde) og atferdsresponser på ulike romlige nivå (unnvikelse av vindkraftverkområdet, en spesifikk turbin eller en i siste øyeblikk unnvikelse fra et rotorblad i bevegelse). Dette bør være et fokusområde for videre arbeid.

Havørn – DNA. Hovedmålsettingen med dette delprosjektet har vært å estimere voksendødelighet blant de hekkende havørnene inne i, og nært opp til vindkraftverket på Smøla basert på mytefjær fra voksne ørner og fjær tatt fra reirunger på hekkeplassene. DNA-analyser av mytefjær har vist seg å være kostnadseffektiv metode for å estimere antall aktive territorier innen området til vindkraftverket. En enkelt kartlegging av hekkeplasser kan føre til at antall hekkende par overestimeres; på Smøla med 15 %. Dette har stor betydning i forhold til evaluering av hvilken som helst havørnbestand. Utvikling og optimalisering av DNA-metoder slik som vi har gjort i dette prosjektet har gitt svært viktige erfaringer og gjort oss i stand til lettere å svare på tilsvarende problemstillinger også når det gjelder andre rovfuglarter. De foreløpige resultatene indikerer at vindkraftverket på Smøla er en viktig dødelighetsfaktor for havørnbestanden på Smøla, og at det står for mer enn 50 % av registrert voksendødelighet. I særdeleshet synes fugler som hekker innenfor eller nært opp til vindkraftverkområdet å være utsatt for vindturbinrelatert dødelighet. En forholdsvis stor andel av de voksne ørnene som er blitt funnet døde i tilknytning til vindkraftverket er ikke representert i vår database over hekkende par. Dette indikerer at en viss andel av voksne ørner i bestanden ikke forsvarer eget territorium, og disse refereres til som ”flytere”.

Flere ubesvarte spørsmål i tilknytning til havørnbestanden på Smøla kan finne sine svar ved hjelp av DNA-analyser. Andelen ikke-territorielle voksne fugler (flytere) i bestanden kan beregnes ved å simulere forventet antall motstykker (*matches*), gitt forekomsten av kjente, hekkende fugler i vår database av voksne ørner. Databasen, som vi benytter til å overvåke “omsetning” og opphav til døde ørner med, gjør det mulig å identifisere hekketerritorier som er spesielt sårbare for vindturbinrelatert dødelighet. Dette er kunnskap som er viktig når det skal gjennomføres adekvate, avbøtende tiltak for å redusere den ekstra dødeligheten som skyldes vindkraftverket. I løpet av prosjektperioden har vi generert en dataserie over fem år som kan benyttes for å beregne voksendødelighet i bestanden. Antall døde fugler og motstykker i databasen er imidlertid likevel relativt lavt. Derfor bør denne tidsserien forlenges slik at beregningen av voksendødeligheten kan bli mer robust. Det vil gjøre oss i stand til å modellere hvordan dødeligheten som er relatert til vindkraftverket påvirker vekstraten i bestanden. I tillegg anbefaler vi at en tilsvarende tidsserie lages for et kontrollområde som ikke er påvirket av vinkraftutbygging. Det vil gjøre oss i stand til å separere dødelighet relatert til vindkraftproduksjon fra annen dødelighet (”bakgrunnsdødelighet”) i en naturlig havørnbestand.

Havørn – hekkesuksess. Hovedmålsettingen med dette delprosjektet har vært å overvåke mulige endringer i hekkebestanden av havørn på Smøla som følge av at vindkraftverket ble bygget, og se om det har hatt noen kort eller langsiktige effekt på ørnenes reproduksjon og hekkesuksess. Så langt er vår konklusjon at havørnbestanden på Smøla er stabil. En avtagende bestand innen området til kraftverket skyldes dødelighet og fortrenging. Antallet havørnunger som er født i løpet av studieperioden (2002-2010) har økt, på samme måte som reproduksjonssuksessen. Antall ørner født innenfor området til vindkraftverket har imidlertid gått ned. Det har også reproduksjonsraten. Dataene fra DNA-analysene er et svært viktig bidrag til overvåkingsdataene, og øker nøyaktigheten til disse vesentlig. Tradisjonelle metoder overestimerer bestandsstørrelsen med 10-15 % sammenlignet med DNA-metoder. Når det gjelder overvåkingsarbeidet av havørnbestanden på Smøla demonstrerer dette viktigheten og betydningen av for- og etterundersøkelser når trender i bestandsutviklingen skal studeres.

Viktige ubesvarte spørsmål knyttet til havørnene på Smøla er knyttet til analysene av voksendødelighet og omsetningsrater i bestanden basert på DNA-data. Dette arbeidet er i gang og vil gjøre det mulig å bygge en bestandsmodell over havørnbestanden Smøla på et mye sikrere grunnlag. Avslutningsvis vil vi modellere de langsiktige effektene på havørnbestanden av dødeligheten som skyldes den ekstra dødeligheten som vindturbinene genererer (planlagt å være ferdig i 2012 i tilknytning til PhD-opplegget for Espen Lie Dahl).

Havørn – obduksjon. Hovedmålsettingen med dette delprosjektet har vært å identifisere dødsårsakene og skademønster til de døde havørnene som er funnet i tilknytning til vindkraftverket på Smøla, og identifisere og karakterisere hvordan skader forårsaket av vindturbiner ser ut sammenlignet med andre, dødelige skadekarakteristika. Røntgenbildene viser et gjennomgående skademønster forårsaket av massive ødeleggelser av skjelettet, med et bredt spekter av frakturer. Noen få enkeltindivider hadde imidlertid bare mindre skader. Flere individer hadde fått kuttet av en vinge, men flertallet hadde flere frakturer i tilknytning til ulike deler av kroppen. Undersøkelsen viser et bilde med komplekse lesjoner som til dels er jevnt fordelt på skjelettet. Frakturmønsteret kan sammenlignes med det en finner hos dyr utsatt for trafikkulykker. Det er ikke uvanlig å finne døde fugler med en eller noen få frakturer på skjelettet, men ikke så omfattende som det disse havørnene fremviser. Antall frakturer er betydelig høyere på et stort antall av kollisjonsofrene enn det en finner hos fugler i områder uten vindturbiner. Et stort antall bein var splintret og hadde skarpe kanter. Det er ikke mulig å forklare disse på annen måte enn ved at fuglekroppene har blitt utsatt for voldsomme og plutselige krefter slik det skjer når det blir truffet av et rotorblad på en vindturbin.

Havørn – sammenligning av atferd innenfor og utenfor området til vindkraftverket. Hovedmålsettingen til dette delprosjektet har vært å observere atferden til havørn innenfor området til vindkraftverket og i kontrollområder som grenser opp mot kraftverksområdet for å skaffe data på atferdsresponsen hos ørnene i forhold til vindturbinene. Hovedkonklusjonen er at havørnene på Smøla ikke synes å ha noen spesielle atferdsresponser på vindturbinkonstruksjonene. Dette kan bidra til å forklare at så vidt mange ørner er funnet døde i området til vindkraftverket. Atferdsforskjellene som er funnet når det gjelder voksne og subadulte individer bidrar til økt forståelse når det gjelder aldersfordelingen mellom kollisjonsofrene som er funnet. Det høye antall voksne fugler sammenlignet med subadulte kan eksempelvis skyldes atferdsforskjellene, eksempelvis det at de voksne bruker mer tid i lufta knyttet til sosiale interaksjoner mellom individer, og når de flyr frem og tilbake mellom hekkeplassen og næringsområdene. Hvis denne atferden øker risikoen for at fuglene skal kollidere med vindturbinene kan dette også bidra til å forklare et høyere antall observasjoner av subadulte innenfor området til vindkraftverket enn utenfor. Dette bør vurderes nøye i analysene av mulige langsiktige effekter av vindkraftverket på havørnbestanden på Smøla. Hvis disse konklusjonene er korrekte, vil det også ha konsekvenser for mulighetene til å utvikle avbøtende tiltak som kan hindre/redusere omfanget av kollisjoner. Resultatene understreker viktigheten av å gjennomføre grundige forundersøkelser når det bestemmes hvor et vindkraftverk bør plasseres, slik at en unngår plassering i områder med fugler som er sårbare for å kollidere med kunstige lufthindre. En mer presis forutsigelse av hvilke perioder som er høyrisikoperioder når det gjelder kollisjoner basert på miljøvariabler som lufttemperatur, vindforhold, nedbør og andre forhold som genererer høy flygeaktivitet i perioden mars-mai vil gjøre det mulig å komme med anbefaliger til vindkraftoperatøren om å stenge ned vindkraftverket – eller enkeltturbiner – i slike høyrisikoperioder for å redusere antall kollisjoner.

Fugleradar. Studier av atferdsmessige responser hos fugl i forhold til menneskeskapte strukturer som vindkraftverket på Smøla, krever måter å observere og dokumentere bevegelse av fugler i interesseområdet. Menneskelig, visuell observasjon forblir en uunnværlig forutsetning og en viktig metode, men et dedikert radarsystem er et kraftig virkemiddel som i stor grad strekker observasjonsevne, både når det gjelder observasjonsperioden, og størrelsen til overvåkingsområdet. Radaren kan eksempelvis settes til å dekke et relativt stort område av vindkraftverket, og driftes 24 timer i døgnet hele året under alle typer værforhold, noe som er en umulig oppgave bare ved bruk av menneskelige observatører alene. Samtidig muliggjør en radar kontinuerlig opptak av radarbilder som gir dokumentasjon av aktivitetene i overvåkingsområdet.

Imidlertid har bruken av radar for dette formålet steds- og systemspesifikke begrensninger som er viktig å være oppmerksom på når de endelige dataene skal evalueres. En viktig del at BirdWind-prosjektet har bestått i å utvikle radarteknologi som redskap for å overvåke og samle data omkring fuglers atferd i nærheten av store vindturbiner. Så vidt vi vet er dette første gang at radar har blitt tatt i bruk i tilknytning til denne type forskning i Norge. Viktige målsettinger i dette delprosjektet har derfor vært å utføre eksperimenter og utvikle nødvendige og riktige metoder, og tilegne seg generelle erfaringer om bruken av fugleradar. En av hovedkonklusjonene er at fugleradar ikke er et redskap som kan benyttes uten forutgående kunnskap omkring teknologiske, metodiske og biologiske aspekter. Vi har utviklet forskjellige praktiske metoder/redskaper for å gjøre det enklere for radarpersonell å finne egnet lokaliseringssted, oppsett og kalibrering av radarutstyret, så vel som utviklet protokoller for å håndtere dataanalysene. Med dette på plass kan en fugleradar gi ny innsikt i atferd hos fugl, ikke minst i tilknytning til mulige effekter av vindkraftverksetablering – både når det gjelder for- og etterundersøkelser. Analysene fra Smøla illustrerer for eksempel variasjonene i vår- og høsttrekk, artsspesifikk atferd, flygeruter når kollisjoner har inntruffet, samt bidrar til å bedre analysegrunnlaget for detaljert unnvikelsesatferd.

Viktige gjenstående spørsmål er knyttet til det faktum at en fugleradar kan gi nær sanntid-informasjon om fugleaktivitet. Dette kan benyttes til å identifisere perioder og områder med økt kollisjonsrisiko. Det gjenstår å utvikle en kollisjonsrisikomodell basert på disse dataene, som kan gi innsikt omkring høy fugleaktivitet innenfor de arealene som rotorbladene dekker, i forhold til den enkelte turbin til enhver tid. Hvis denne modellen viser seg å ha prediksjonskraft, verifisert gjennom observerte kollisjoner, kan den ha potensial til å advare personell i vindkraftverket slik at enkeltturbiner kan stanses. Dataene som er samlet fra april 2008 frem til i dag må analyseres med hensyn på å korrelere med årstid, tidspunkt på dagen og værforhold (for eksempel vindhastighet og –retning, sikt m.m.). Ved å sammenligne disse mønstrene med inntrufne kollisjoner og eksempelvis værparametre (spesielt vindhastighet) kan det bidra til å danne grunnlag for og gi råd om avbøtende tiltak som eksempelvis nedstengning av turbiner under gitte betingelser. MERLIN-radaren som vi har benyttet i vindparken på Smøla gir kun innsikt i lokale bevegelsesmønstre hos fugl. Når det gjelder etablering av vindkraftverk langs norskekysten vil det være viktig med kunnskap om storskala trekkruter hos fugl. Vi ønsker å undersøke om dette lar seg gjøre ved å ekstrahere data fra de store 3D-radarsystemene som Luftforsvaret og Meteorologisk institutt disponerer. I dag er vår kunnskap om disse storskala trekkrutene bare basert på gjenfunn av ringmerkede fugler, hvilket ikke gir tilstrekkelig informasjon til å gi gode råd om etablering av vindkraftverk.

Metoder og teknologi for avbøtende tiltak mot fuglekollisjoner i vindkraftverket på Smøla. Hovedmålsettingen for dette delprosjektet har vært å vurdere effektiviteten til kjente redskaper og kjent teknologi som kan bidra til redusere fugledødelighet i tilknytning til vindkraftverk. Basert på konklusjoner fra denne gjennomgangen er konkrete tiltak som kan tenkes å redusere omfanget av dødelighet hos havørn i tilknytning til vindkraftverket på Smøla vurdert. En av hovedkonklusjonene er – selv om delprosjektet ikke har lyktes å nå de opprinnelige målsettingene – at de erfaringer som er gjort, og den økte innsikt som er oppnådd omkring kompleksiteten i dette spørsmålet, danner et godt grunnlag for videre arbeid. For å lykkes med avbøtende tiltak som kan bidra til å redusere kollisjonsrisikoen for havørn og smølalirype, er det en forutsetning å øke den artsspesifikke kunnskapen om hvordan disse artenes atferd reguleres ut fra syn (evne til å oppfatte farger, bevegelsessensibilitet m.m.), og på hvilken avstand visuelle stimuli registreres. Økt kunnskap om hvordan fugler – basert på den enkelte arts aerodynamiske forutsetninger – kan kontrollere vindturbinindusert turbulens, er også viktig. Uten slik kunnskap er det vanskelig å vurdere hvordan eksempelvis havørn ser og tolker bevegelsene til rotorbladene og andre vindturbintilknyttede strukturer.

Økt kunnskap omkring viktige parametre knyttet til artsspesifikk biomekanikk er en forutsetning for å ta vår forståelse omkring vindturbinrelatert dødelighet hos fugl et skritt videre. Å skulle modifisere konstruksjonen til en vindkraftturbin i retning av en mer fuglevennlig design krever eksempelvis kunnskap om hvordan rotorbladenes hastighet og design modifiserer den genererte turbulensen, og hvordan disse parametrene modifiseres av lokal topografi og vindforhold. Det er også viktig å forstå om valg av fluktmønster hos en fugl er påvirket av turbinindusert turbulens på en måte som kan forutsies. Det er så langt uklart om en del kollisjoner mellom fugl og vindturbiner forårsakes av at fuglen ikke oppfatter rotorbladene pga. deres hastighet (bevegelsesblindhet), eller om den er fanget i turbulensen og ikke klarer å kontrollere egen flukt pga. biomekaniske begrensninger slik at den dras inn mot rotorbladene. Det kan også tenkes at turbulensen skaper virvler og luftlommer med økt/senket lufttrykk som hindrer oppdrift og som kan føre til fritt fall til bakken og påføres fatale skader. Ved å utvikle funksjonelle kamerasystem bør det være mulig å samle data som kan besvare noen av spørsmålene som er knyttet til hvordan bl.a. rovfugl og hønsefugl oppfører seg når de befinner seg nært opp til en vindturbin. Sammen med økt kunnskap om deres syn og biomekaniske ferdigheter, kan mulige endringer i fluktmønster analyseres og kobles til adekvate parametre og lokale vindforhold (eksempelvis reaksjonsavstand fra turbinen, hvor raskt de reagerer, unnvikelsesavstand og unnvikelsesatferd). Dette gjør det mulig å optimalisere bruk av kamerateknologi som kan støtte opp om den teoretiske tilnærmingen for å forstå betydningen av den enkelte fugleartes syn og biomekaniske forutsetninger.

Dataflyt og lagringssystemer. Hovedmålsettingen ved dette delprosjektet har vært å utvikle en omfattende, teknisk infrastruktur for effektiv dataflyt, lagring, opphenting, håndtering og analyse av dataene fra videokamerasystemet ved turbin 43, dataene fra MERLIN-radaren og satellittelemetridataene. Fugleradarsystemet genererer store datamengder når det er stor aktivitet av fugl innenfor og i nærområdene til vindkraftverket. Rådataene prosesseres på stedet og dette resulterer i to nye Microsoft Access databasefiler hver dag for henholdsvis det vertikale og horisontale radarsystemet. Hver natt kl 0200 startes en overføringsjobb som håndterer og overfører datafilene til den sentrale filserveren hos NINA i Trondheim. Deretter tar en ny håndteringsjobb tak i disse filene, prosesserer dem, og forsyner den sentrale databaseserveren med nye posteringer. De seks kameraene som er posisjonert rundt turbin 43 har generert store datamengder, ettersom hvert kamera tar 6 bilder i sekundet (fps) når en bevegelse detekteres. Disse dataene overføres til NINA i Trondheim og lagres i den tilknyttede lagringsløsningen. Et eget dataprogram benyttes for å studere disse opptakene. Fugleradaren og kamerasystemet er tilkoblet via radiosamband, som også gir internetttilgang. En lokal internettleverandør (NEAS) sørger for internett-tilkoblingen fra radar-/kamerasystemene (10 Mbit/s). Mellom Smøla og Trondheim har vi en VPN-tunnel for sikker dataoverføring.

Lagringssystemet består av en HP ProLiant server med to SAN-tilknyttede disksystemer med en total kapasitet på 8 TB (TeraByte). Lagringsserveren kjører Microsoft Windows Server 2003 Storage Edition og EMC DiskXtender for Windows, noe som gir en effektiv datahåndtering av flere typer data. EMC DiskXtender for Windows forflytter inaktive eller sjelden brukte filer til datakassetter i et HP StorageWorks MSL4048 tapebibliotek som gir inntil 76.8 TB lagringskapasitet uten å endre brukertilgangen. Systemet for dataflyt ble etablert i 2008, og har fungert slik som planlagt. Det har imidlertid vært nødvendig å “justere” dataflyten, samt dele dataene inn i ullike databaser og filområder for å oppnå bedre ytelse ved ”spørring” mot de mest interessante delene av dataene. ”Fugle-spordatabasen” vokser svært raskt (flere hundre millioner observasjoner) og med slike datamengder er adekvat filtrering og oppsplitting av dataene avgjørende.

GIS, visualisering og terrengmodellering. Hovedmålsettingen med dette delprosjektet har vært å visualisere fuglenes aktivitetsmønster i 3D, samt etablere metoder og lage modeller som kan påvise potensielle konfliktområder for fugl og vindkraftverk. Størst innsats har vært rettet mot terrengmodellering, siktlinjestudier og bakkekluttermodellering. GIS-modellering og presise høydedata (LIDAR) brukt til siktlinjestudier og bakkecluttermodellering har bidratt vesentlig for å optimalisere radarlokaliseringen innenfor området til vindkraftverket på Smøla, samt identifisere potensielle falske fugle-spor (”tracks”) innenfor de teoretiske bakkeclutterområdene lagret i MERLIN-databasen for horisontale radarobservasjoner. Modellene er fleksible og lette å lage. Bakkeclutterfilteret er nå implementert i databasen. Hvert spor som er identifisert innenfor bakkeclutterfilteret blir automatisk markert som et potensielt falskt spor. Bakkeclutteret synes å korrelere godt i forhold til klutterområdene identifisert gjennom de statiske clutterkartene generert av MERLIN. Det er imidlertid en del ubesvarte spørsmål, bl.a. i forhold til de modellerte refleksjonsegenskapene til terrenget som må sammenlignes statistisk med det statiske clutterkartet i MERLIN. Spørmålet er hvordan en skal kunne ekstrahere landclutter-reflektivitetsverdiene fra MERLIN-prosessoren. Et annet nokså komplekst spørsmål er hvordan turbininterferensen skal modelleres, dvs. det kraftige clutteret som reflekteres fra stripen av bakkeclutter bak hver vindturbin. Dette er ekko som er forårsaket av energi reflektert fra motordelen (nacellen) og turbinbladene mot bakken bak den enkelte vindturbin, og som tar samme veien tilbake til radaren. Dette er clutter som varierer med vinkelen til nacellen (dvs. vindretningen) og som også kan observeres som ”blafring” på radarskjermen når turbinbladene beveger seg. Denne komplekse, temporære variasjonen gjør at det er clutter som er spesielt vanskelig å hanskes med i den automatiske prosesseringen. Det har heller ikke lykkes å modellere radardetekterte fugle-spor i 3D slik som opprinnelig planlagt av den enkle grunn at MERLIN ikke er en 3D radar. Hvis det lykkes å merke voksne havørn med 3D GPS-sendere i 2011, kan dette imidlertid åpne for å korrelere noen av disse 3D-GPS fuglesporene med data i basen for horisontalradaren i MERLIN slik at det blir mulig å studere og visualisere de observerte aktivitetene i 3D.

12 Publications, lectures, coverage in public media and conference participation

12.1 Publications

Bevanger, K. 2007. Vindkraft og miljø. – NINA Årsmelding 2006: 6.

Bevanger, K., Follestad, A., Gjershaug, J.O., Halley, D., Hanssen, F., Johnsen, L., May, R., Nygård, T., Pedersen, H.C., Reitan, O. & Steinheim, Y. 2008. ”Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway”. Status report 1st January 2008. – NINA Report 355: 33 pp.

Bevanger, K., Clausen, S., Flagstad, Ø. Follestad, A., Gjershaug, J.O., Halley, D., Hanssen, F., Lund Hoel, P., Jacobsen, K.-O., Johnsen, L., May, R., Nygård, T., Pedersen, H.C., Reitan, O., Steinheim, Y. & Vang, R. 2008. ”Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway”. Progress Report 2008. NINA Report 409. 55 pp.

Bevanger, K., Berntsen, F., Clausen, S., Dahl, E.L., Flagstad, Ø., Follestad, A., Halley, D., Hanssen, F., E., Hoel, P.L., Johnsen, L., Kvaløy, P., May, R., Nygård, T., Pedersen, H.C., Reitan, O., Steinheim, Y. & Vang, R. 2009. ”Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway” (BirdWind). Progress Report 2009. - NINA Report 505. 70 pp.

Bevanger, K., Berntsen, F., Clausen, S., Dahl, E.L., Flagstad, Ø., Follestad, A., Halley, D., Hanssen, F., E., Hoel, P.L., Johnsen, L., Kvaløy, P., May, R., Nygård, T., Pedersen, H.C., Reitan, O., Steinheim, Y. & Vang, R. 2009. ”Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway” (BirdWind). Progress Report 2009. - NINA Report 505. 70 pp.

Follestad, A., Reitan, O., Nygård, T., Flagstad, Ø. & Schulze, J. 2007. Vindkraft og fugl på Smøla 2003-2006. - NINA Rapport 248. 74 pp.

Follestad, A. 2008. Vindkraft. S. 63-74 - I: Christensen-Dalsgaard, S., Bustnes, J.O., Follestad, A., Systad, G.H., Mittet Eriksen, J., Lorentsen, S.-H. & Anker-Nilssen, T. (red.). Tverrsektoriell vurdering av konsekvenser for sjøfugl. Grunnlagsrapport til en helhetlig forvaltningsplan for Norskehavet. NINA Rapport 338. 161 s.

Halley, D.J. & Hopshaug, P. 2007. Breeding and overland flight of red-throated divers *Gavial stellata* at Smøla, Norway, in relation to the Smøla wind farm. – NINA Report 297. 32 pp.

May, R. & Nygård, T. 2009. Spatial assessment of white-tailed sea eagle collision risk at the onshore wind-power plant on the island of Smøla. 2nd European Congress of Conservation Biology. Conservation biology and beyond: from science to practice. Czech University of Life Sciences, Prague. September 1-5, 2009.

Nygård, T, Bevanger, K. & Reitan, O. 2008. Forholdet mellom fugler, vindmøller og andre lufthindringer. En litteraturoversikt. - NINA Rapport 413: 167 s.

Nygård, T., Bevanger, K., Dahl, E. L., Flagstad, Ø., Follestad, A., May, R., Reitan, O. & Schulze, J. 2009a. Juvenile White-tailed Sea Eagles’ (*Haliaeetus albicilla*). Movement Patterns at Smøla Wind-farm in Norway Determined by Satellite Telemetry. Raptor Research Foundation annual meeting. Pitlochry, Scotland. 30. Sept. - 3. Oct. 2009.

Nygård, T., Jacobsen, K.-O. & Dahl, E. L. 2009b. The use of satellite transmitters in eagle research in Norway. Microwave Telemetry, Inc. 2009 bird and fish tracking conference. Elliot City, Maryland, USA. 24-26 March 2009.

Nygård, T., Bevanger, K., Dahl, E. L., Flagstad, Ø., Follestad, A., Hoel, P. L., May, R. & Reitan, O. 2010. A study of White-tailed Eagle *Haliaeetus albicilla* movements and mortality at a wind farm in Norway. - Proceedings of the BOU’s 2010 Annual conference. Climate change and Birds. http://bouproc.blogspot.com/2010/09/climate-change-and-birds.html.

Reitan, O. & Nygård, T. 2008. Vindkraft och havsörnbiologi samt kartläggning av unga havsörnars rörelsesmönster m.h.a. satelittelemetri. - In Hjernquist, M., Hjernquist, M., Hägerroth, J.-E., Johansson, T. & Martinsson, M., (eds.). Kungsörnsymposium 2007. Gotlands ornitologiska förening, Länsstyrelsen Gotlands län, Gotland. Pp. 11-12.

12.2 Lectures and conference participation

Bevanger, K. 2007. Vindkraft og fugl. – Foredrag på Produksjonsteknisk konferanse EBL, Gardermoen 7. mars.

Bevanger, K. 2008. Konsekvenser av vindkraftutbygging for fugl/vilt. - Foredrag for grunneiere og Agder Energi Produksjon. Kvinesdal 2. juli.

Bevanger, K. 2008. A brief summary of the Smøla wind power project. Årlig møte i Vindkraftprosjektet. - Havfiskesenteret, Smøla. 11-12 March 2008.

Bevanger, K. 2008. Introductory remarks on project status. – Wind Power Seminar at NINA 28 November. Trondheim.

Bevanger, K. & Johnsen, L. 2008. Installed camera systems. – Wind Power Seminar at NINA 28 November. Trondheim.

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

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

Bevanger, K. 2009. Research activities on Smøla focusing bird responses to the wind-power plant. Foredrag i tilknytning til Bernkonvensjonens “On the spot apprisal”, Smøla 16 June 2009.

Bevanger, K. 2009. Introduction and a brief summary of the Smøla wind-power project. Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla.

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

Bevanger, K. BirdWind. TrønderEnergi, Trondheim. 20.11.2009.

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

Bevanger, K. Vindkraft og havørn på Smøla – når og hvorfor kan vindkraft være et problem for fugl? Nordisk Ministerråd; NordVind-gruppen. København 03.11.2010.

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

Bevanger, K. Project status. BirdWind Annual Meeting, Smøla 22.03.2010.

Bevanger, K. Biological rationale for a camera monitoring system. BirdWind Annual Meeting, Smøla 22.03.2010.

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

Clausen, S. & Vang, R. 2008. Data flow and storing systems from camera installations and avian radar on Smøla to NINA. - Wind Power Seminar at NINA 28 November. Trondheim.

Dahl, E.L. 2008. Do wind power developments affect breeding biology in White-tailed Sea Eagle, *Haliaeetus albicilla*? - Årlig møte i Vindkraftprosjektet. Havfiskesenteret, Smøla. 11-12 March 2008.

Dahl, E.L. 2008. White-tailed sea eagle – breeding and reproduction success on Smøla. - Wind Power Seminar at NINA 28 November. Trondheim.

Dahl, E.L. & Nygård, T. 2009. Havørn og vindkraft på Smøla. Presentasjon for TrønderEnergi 20.11.2009. Trondheim.

Dahl, E.L. 2009. Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway. Foredrag på Energiregion Møre sin energileir for lærere. 22.09.2009, Smøla

Dahl, E.L. 2009. White-tailed eagle in Smøla Windfarm. Monitoring and population modeling. Foredrag under høringsmøte Bernkonvensjonen. 16.06.2009, Smøla

Dahl, E.L. 2009. White-tailed eagle in Norway. Monitoring and population modeling. Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla.

Dahl, E. L. BirdWind. Gaglunsjforedrag på SINTEF 11.10.2010, Elektrobygget, Trondheim.

Dahl, E. L. Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway (BirdWind). Grunneiermøte organisert av Statkraft om Smøla Vindpark 25.05.2010. Smøla.

Dahl, E. L. BirdWind. Avdelingsmøte i Direktoratet for naturforvaltning 06.05.2010, Trondheim.

Dahl, E. L. Population dynamics in white-tailed eagle at an on-shore windfarm in coastal Norway. Stipendiatsamling CEDREN, Sintef Energiforskning, Gløshaugen 14.04.2010.

Dahl, E. L. White-tailed eagle population monitoring. BirdWind Annual Meeting, Smøla 22.03.2010.

Dahl, E. L. Vindkraft og mulige negative konsekvenser for fugleliv? Miljøvernkonferansen 2010, Fylkesmannen i Sør-Trøndelag, Miljøvernavdelingen. Ørland Kysthotell 09.03.2010

Dahl, E. L. White-tailed eagles in Smøla Windfarm. Vindkraftseminar Høgskolen på Gotland, Visby, Gotland 24.02.2010.

Dahl, E. L., Bevanger, K., Nygård, T., Røskaft, E., Stokke, B. G. Windfarms are affecting white-tailed eagle (Haliaeetus albicilla) breeding success. International Ornithological Congress 2010, Campos do Jordao, Brasil 24.08.2010.

Dahl, E.L., Reitan, O., May, R. & Follestad, A. Standardvilkår for KU, for- og etterundersøkelser av vindkraftverk. Workshop Samlet belastning vindkraft, NVE, Oslo. 14.09.2010.

Desholm, M. A consensus paper on radar ornithology. BirdWind Annual Meeting, Smøla 22.03.2010.

Flagstad, Ø., Follestad, A. & Lie Dahl, E. Genetic analyses of the white-tailed eagle population on Smøla. BirdWind Annual Meetin, Smøla 22.03.2010.

Follestad, A. 2007. Smøla wind farm and White-tailed eagles. - Scottish Raptor Study Group Conference, Central Scottish Raptor Study Group. Perth, Scotland, 24. februar.

Follestad, A. 2007. Miljøutfordringer ved vindkraft. - Kurs om vindenergi for lærere i realfag i u.skole og v.g.s., Energiregion Møre og Smøla Vindkraftkontor. Smøla, 5. juni.

Follestad, A. 2007. Vindkraft og havørn. - NVEs vindkraftseminar 2007. Oscarsborg festning, 29. juni.

Follestad, A. 2007. Vindkraft og havørn. - Åpent møte, Vern Kysten, Snillfjord. Krokstadøra, 30. august.

Follestad, A. 2007. Smøla wind farm and white-tailed eagles. – Foredrag for sørafrikansk delegasjon på besøk hos DN/MD 17. oktober.

Follestad, A. 2007. Konflikten havørn - vindmøller. - Kurs i miljøjournalistikk - tema biologisk mangfold, Institutt for journalistikk. Fredrikstad, 30. november.

Follestad, A. 2008. Monitoring of breeding WTE at Smøla: population size, distribution, reproduction and DNA-studies. - Årlig møte i Vindkraftprosjektet. Havfiskesenteret, Smøla. 11-12 March 2008.

Follestad, A. 2008. Smøla wind farm and white-tailed eagles. - Foredrag for delegasjon fra Sør-Afrika på besøk hos DN/MD. DN. 2. september.

Follestad, A. 2008. Miljøutfordringer knyttet til utbygging av vindkraft i Norge. - Foredrag på kurs om vindenergi for realfagslærere. Energiregion Møre og Smøla kommune. Smøla. 27. mai.

Follestad, A. 2008. Vindkraft og biologisk mangfold. Tar vi problemene på alvor? - Foredrag på årsmøtet til NORWEA (Norsk vindkraftforening). Oslo. 7. april.

Follestad, A. 2008. Miljøutfordringer i dagens samfunnsutvikling. - Foredrag på gründercamp for realfag. Ungt Entreprenørskap Sør-Trøndelag og NTNU. NTNU, Trondheim. 6. mars.

Follestad, A. 2008. Vindkraft og havørn på Smøla. - Foredrag på åpent info og diskusjonsmøte - vindkraft. Senter for Fornybar Energi, NTNU-SINTEF-IFE. Trondheim. 25. januar.

Follestad, A. & Flagstad, Ø. 2008. Preliminary results of Smøla white-tailed sea eagle DNA-analyses. - Wind Power Seminar at NINA 28 November. Trondheim.

Follestad, A. 2009. Sum-effects of wind power development and environmental aspects connected to offshore wind turbines. Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla.

Follestad, A. Wind power and possible conflicts with birds and nature types. Seminar for studenter ved NTNU. Trondheim 07.10.2010.

Follestad, A., May, R., Reitan, O., Dahl, E. L. & Bevanger, K. Samlet belastning - avgrensing av begrepet. Workshop - samlet belastning vindkraft. NVE Hovedkontor Oslo 14.09.2010.

Follestad, A., Reitan, O., Nygård, T. & Dahl, E. L. Vindkraft og biologisk mangfold. Seminar for studenter fra HiNT om naturforvaltning. Trondheim.

Gjershaug. J.O. 2008. Wind power and the eagle owl. - Wind Power Seminar at NINA 28 November. Trondheim.

Halley, D. 2008. Red-throated diver and small bird monitoring in relation to the Smøla wind power installation. - Årlig møte i Vindkraftprosjektet. Havfiskesenteret, Smøla. 11-12 March 2008.

Hanssen, F. 2008. GIS use in terrain modelling on Smøla. - Wind Power Seminar at NINA 28 November. Trondheim.

Hanssen, F. 2009. Terrain and clutter modeling – the road ahead. Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla.

Hanssen, F., Kvaløy, P., May, R., Steinheim, Y. & Vang, R. BirdWind Smøla. Radardeteksjon av fugl. GIS brukerforum 2010 Tronheim, Asplan Viak Internet AS, Trondheim 15.04.2010.

Hanssen, F., May, R. & Steinheim, Y. Surface clutter modeling. European MERLIN user conference, Bureau Waardenbourg, Culembourg, The Netherlands, 25/26. 01.2010.

Hoel, P.L. 2009. Do the wind-power plant on Smøla affect the WTSE behaviour? Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla.

Håstad, O. 2008. “The status of vision”. Årlig møte i Vindkraftprosjektet. - Havfiskesenteret, Smøla. 11-12 March 2008.

Johnsen, L. 2008. Detection and sensor systems – a status report. - Årlig møte i Vindkraftprosjektet. Havfiskesenteret, Smøla. 11-12 March 2008.

Johnson, N.H. 2008. Birds and windfarms. Comments from NVE. - Årlig møte i Vindkraftprosjektet. Havfiskesenteret, Smøla. 11-12 March 2008.

Johnsen, L. 2009. Camera monitoring – further development of the project and views on lights to make the wind turbines more visible (in situ or an experimental design to test UV-light, flashing frequencies etc. Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla.

Johnsen, L. Camera monitoring system on Smøla - Hardware and software constraints. BirdWind Annual Meeting. Smøla. 22.03.2010.

Langston, R. 2008. Wind Farms and Birds: research update. - Årlig møte i Vindkraftprosjektet. Havfiskesenteret, Smøla. 11-12 March 2008.

Lund-Hoel, P. 2008. Behaviour of the white-tailed sea eagle: an evaluation of collision risk with windmills at Smøla. - Årlig møte i Vindkraftprosjektet. Havfiskesenteret, Smøla. 11-12 March 2008.

Lund-Hoel, P. 2008. Behaviour of the white-tailed sea eagle in a wind farm area at Smøla on the Norwegian coast - International workshop on birds of prey and wind farms. Berlin. 21-22 October 2008.

Lund-Hoel, P. 2008. White-tailed sea eagle behaviour inside and outside the wind-power plant area. - Wind Power Seminar at NINA 28 November. Trondheim.

May, R. 2008. ”What I intend to do as a postdoc”. - Årlig møte i Vindkraftprosjektet. Havfiskesenteret, Smøla. 11-12 March 2008.

May, R. 2008. Vindkraftprosjektet Smøla. – Vindkraftmøte med Poland, Statkraft, Smøla.

May, R. 2008. Radar data collecting studies – data analysing methods. - Wind Power Seminar at NINA 28 November. Trondheim.

May, R., Bevanger, K., Hanssen, F., Vang, R., Nygård, T., Dahl, E. L., Clausen, S. & Smith, A. 2008. Radar studies on white-tailed sea eagle at an onshore wind farm on Smøla. - Nordic golden eagle symposium, Tromsø.

May, R., Bevanger, K., Hanssen, F., Vang, R., Nygård, T., Dahl, E. L., Clausen, S. & Smith, A. 2008. Radar studies on white-tailed sea eagle at an onshore wind farm on Smøla. - International workshop on birds of prey and wind farms. Berlin. 21-22 October 2008.

May, R. 2009. 1 year's worth of Bird Radar: what have we learned? Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla.

May, R. 2009. Radar studies on white-tailed sea eagle at the onshore wind park on the island of Smøla. Presentasjon for Vitenskapsmuseet 12.05.2009 Smøla.

May, R. 2009. Spatial assessment of collision risk in white-tailed sea eagle at the onshore wind-power plant on the island of Smøla. Foredrag i tilknytning til Bernkonvensjonens “On the spot appraisal” 16.06.2009 Smøla.

May, R. 2009. Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway. Presentasjon for NTNU Summer school 15.07.2009 Smøla.

May, R. 2009. *Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway*. Foredrag på Miniseminar MSc-programmet i Natural Resources Management (NTNU/NINA/DN) 11.11.2009, Trondheim.

May, R. & Nygård, T. 2009. Spatial assessment of white-tailed sea eagle collision risk at the onshore wind-power plant on the island of Smøla. Foredrag på European Conference for Conservation Biology (Society for Conservation Biology) 03.09.2009, Prag, Tsjekkia.

May, R. 2009. Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway. Tools and Techniques. Presentasjon for TrønderEnergi 20.11.2009. Trondheim.

May, R., Nygård, T., Engen, S., Reitan, O., Dahl, E. L., Bevanger, K., & Hanssen, F. Spatial assessment of white-tailed eagle collision risk at the Smøla onshore wind-power plant in central Norway. Wind Wildlife Research Meeting, Lakewood (CO) USA 19.10.2010.

May, R. BirdWind: Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway. Merlin User Meeting, Bureau Waardenburg, Culemborg (NL). 25.01.2010.

May, R. Natur eller vindkraft? Ja takk begge deler! NINA-dagan 2010, NINA, Tromsø. 09.02.2010.

May, R. Status, clutter modelling and data mining. BirdWind Annual Meeting. Smøla. 22.03.2010.

May, R. Presentation BirdWind-project: Wind-power plant visit and avian radar. Presentation BirdWind-project, NINA, Smøla. 04.05.2010.

May, R. Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway (BirdWind). CEDREN generalforsamling, Trondheim. 06.05.2010.

May, R., Dahl, E. L., Bevanger, K., Nygård, T., Flagstad, Ø., Follestad, A. & Reitan, O. Research on White-tailed eagles at Smøla wind-power plant. CEDREN generalforsamling, Trondheim 06.05.2010.

Nygård, T. 2007. Satellittstudier av unge havørners bevegelseri vindparkområdet på Smøla. Foredrag. Fagsamling vindkraft. Smøla. 26.-27. mars.

Nygård, T. 2006. Wind-power and White-tailed sea eagles in Norway. - NAOC annual conference. Veracruz, Mexico. 9. oktober.

Nygård, T., Follestad, A., Reitan, O. & Dahl, E.L. 2007. Kartlegging av unge havørners bevegelser på Smøla ved bruk av satellittelemetri. - Kungsörnsymposium. Holmhallar, Gotland, Sverige. 28. september.

Nygård, T. 2008. Bird research at Smøla windfarm 2003-2008. - International workshop on birds of prey and wind farms. Berlin. 21-22 October 2008.

Nygård, T. 2008. Studying young white-tailed sea eagles at Smøla using satellite telemetry. - Årlig møte i Vindkraftprosjektet. Havfiskesenteret, Smøla. 11-12 March 2008.

Nygård, T. 2008. White-tailed sea eagle telemetry data – a preliminary risk assessment. - Wind Power Seminar at NINA 28 November. Trondheim.

Nygård, T. 2008. A dynamic database for anthropogenic disturbance publications on birds. - Wind Power Seminar at NINA 28 November. Trondheim.

Nygård, T., Bevanger, K., Dahl, E.L., Flagstad, Ø., Follestad, A., Halley, D., May, R., Pedersen, H.C., Reitan, O. & Schultze, J. 2009. Juvenile White-tailed Eagles' Movement Patterns at Smøla Wind-farm in Norway Determined by Satellite Telemetry. Foredrag på Raptor Research Foundation Annual Meeting (Raptor Research Foundation) 02.10.2009, Pitlochry, Skottland.

Nygård, T., Jacobsen, K.-O. & Dahl, E.L. 2009. The use of satellite transmitters in eagle research in Norway. Microwave Telemetry, Inc. 2009 bird and fish tracking conference. Elliot City, Maryland, USA. 24-26 March 2009.

Nygård, T., Bevanger, K., Berntsen, F., Dahl, E. L., Flagstad, Ø., Follestad, A. May, R. & Reitan, O. Research on White-tailed Eagles at Smøla wind-power plant. BOU Annual Conference, Leicester, England. 07.04.2010.

Nygård, T., Bevanger, K., Berntsen, F., Dahl, E. L., Flagstad, Ø., Follestad, A., May, R., Pedersen, H. C., Reitan, O., Schultze, J. & Hoel, P. L. 2010. A satellite telemetry study of the

White-tailed Eagle at Smøla 2003-2009 (-2011). BirdWind Annual Meeting. Smøla. 22.03.2010.

Nygård, T. 2010. Research on effects on birds in Smøla vindpark. Lecture for NTNU students at Smøla vindpark, Oct 1, 2010.

Nygård, T. 2010. BirdWind-prosjektet Vindkraft og fugl på Smøla. Møte med Statkraft Sverige og Södra, Smøla, 02.02.2010.

Pedersen, H.C. 2008. Willow ptarmigan – wind turbines. - Årlig møte i Vindkraftprosjektet. Havfiskesenteret, Smøla. 11-12 March 2008.

Pedersen, H.C. 2008. Willow ptarmigan – wind turbines. Status for population and telemetry studies. - Wind Power Seminar at NINA 28 November. Trondheim.

Pedersen, H.C. 2009. Why are the ptarmigan killed within the Smøla wind-power plant – and what are the consequences for the ptarmigan population? Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla.

Pedersen, H.C. Willow ptarmigan studies on Smøla. BirdWind Annual Meeting. Smøla. 22.03.2010.

Reitan, O. 2007. Søk etter døde ørner i vindparken på Smøla. Statkraft medarbeidermøte, Smøla. 29. august.

Reitan, O. 2007. Vindkraft og havørn. Medarbeiderseminar for Veterinærinstituttene. Trondheim. 25. september.

Reitan, O. 2007. Vindkraft og havørn. Kungsörnsymposium, Holmhällar, Gotland. 28. september.

Reitan, O. 2008. Fugler og vindmøllene på Smøla - prosjekter vi arbeider med. – Foredrag og demonstrasjoner for HMS-personell Statkraft & Statoil, Smøla 23. april.

Reitan, O. 2008. Smøla wind farm - search for dead birds. - Årlig møte i Vindkraftprosjektet. Havfiskesenteret, Smøla. 11-12 March 2008.

Reitan, O. 2008. Mortality studies on Smøla. - Wind Power Seminar at NINA 28 November. Trondheim.

Reitan, O. Mortality studies – status and methodological challenges. BirdWind Annual Meeting. Smøla. 22.03.2010.

Steinheim, Y. International Conference and Workshop on Radar Ornithology and Entomology 25.-28. juni 2007. Helgoland, Tyskland.

Steinheim, Y. 2008. Avian radar. NINA KMB. - Årlig møte i Vindkraftprosjektet. Havfiskesenteret, Smøla. 11-12 March 2008.

Steinheim, Y. 2008. Merlin radar: Performance evaluation for bird monitoring in the wind-power plant on Smøla. - Wind Power Seminar at NINA 28 November. Trondheim.

Steinheim, Y. Detection constraints and target tests. BirdWind Annual Meeting. Smøla. 22.03.2010.

Steinheim, Y. & May, R. NINA Radar Performance Verification. Merlin User Meeting, Bureau Waardenburg, Culemborg (NL). 25.01.2010.

Steinheim Y. Radar, an introduction to basic performance. Presentation at the international workshop: Trends in Radar Ornithology, National Environmental Institute (NERI), Aarhus University Denmark ,21.01.2010.

12.3 Coverage in public media

NRK TV (riks): Schrødingers katt, 19. april 2007. Om vindmøller til havs (Arne Follestad).

NRK Radio (lokal): Møre og Romsdal 29. juni 2007. Vindkraft og havørn (Arne Follestad)

NRK TV (lokal): Møre og Romsdal lokal 9. mai 2007. Funn av ny ørn under vindmølle. Intervju i felten på Smøla (Ole Reitan).

A-Magasinet 20. april 2007. Snuser opp drepte ørner (Ole Reitan, Kjetil Bevanger)

NRK Møre og Romsdal - 04.02.2008: Om havørn og vindkraft på Smøla.

NRK Møre og Romsdal - 12.03.2008: Fugleradar ved vindmøllene. Kjetil Bevanger

Tidens Krav - 16.03.2008: Kartlegger fuglens flukt. Kjetil Bevanger

Adresseavisen - 28.02.2008: Setter opp ørneradar på Smøla. Kjetil Bevanger

Nordvestnytt – 14.05.2008: Trapper opp forskning. Kjetil Bevanger

NRK Trøndelag – 10.06.2008: Tatt av vindmøller. Kjetil Bevanger
Tidens Krav – 10.06.2008: Fant 24 vindmølledrepte fugler. Kjetil Bevanger
Fiskeribladet Fiskaren – 10.06.2008: Vindkraftverk dreper. Kjetil Bevanger
Tidens Krav – 13.06.2008: Firbeint assistent i vindparken. Ole Reitan (http://www.tk.no/nyheter/article3603699.ece)
Telewizja Polska (polsk nasjonal-TV, TVP) – 29.08.2008: Vindkraftprosjektet Smøla. Roel May
NRK Trøndelag – 26.09.2008: 20 havørner drept på Smøla. Kjetil Bevanger
Adresseavisen - 10.12.2008. Vindmøllene dreper mer ørn. Kjetil Bevanger.
Tidens Krav – 12.12.2008. 31 døde fugler funnet hittil i år. Kjetil Bevanger.
TV2 – 13.12.2008. Vindmøller skaper fugledød. Kjetil Bevanger.
NRK1 TV Schrödingers katt – 19.03.2009. Vindkraft og havørn. Kjetil Bevanger, Espen Lie Dahl, Roel May, Ole Reitan.
NRK Møre og Romsdal – 25.03.2009. Turbinar tek ørn. Kjetil Bevanger.
Petromagasinet - 26.03.2009. Statkraft forsker på havørn. Kjetil Bevanger.
Svenska Dagbladet – 10.06.2009. Vindkraftens tillväxt fara för fågellivet. Kjetil Bevanger
Tidens Krav – 05.10.2009. Ingen fare for havørna. Kjetil Bevanger.
Nationen - 12.10.2009. Vindmøller mot havørn. Ole Reitan.
Aftenposten – 15.10.2009. Tar mer ryper enn jegerne. Kjetil Bevanger.
Jakt & Fiske 16.10.2009. Rypas største trussel. Kjetil Bevanger.
Norges Jeger- og Fiskerforbund – 26.10.2009. Jakt med elektrisk spenning. Kjetil Bevanger.
VG Helg – 21.10.2009. Smøla vindpark, havørn og Bernkonvensjonen. Espen Lie Dahl
Vest-Telemark Blad - 04.11.2010. Verdenskonferanse om vindkraft og vilt. Kjetil Bevanger
NINA – 03.11.2010. Verdenskonferanse om vindkraft og vilt. Kjetil Bevanger
NRK P1/Naturens verden – 10.10.2010. Havørna i Smøla vindpark. Espen Lie Dahl
Foto.no – 28.09.2010. Havørn workshop på Smøla med Nordic Light. Espen Lie Dahl
Tidens Krav – 13.09.2010. Med kamera i havørnens rike. Espen Lie Dahl
Adresseavisen – 03.09.2010. Frykter 20000 døde fugl i året. Kjetil Bevanger
Foto.no – 01.09.2010. Nordic Light Workshops presenterer Havørnfotografering på Smøla. Espen Lie Dahl
Fotografi.no – 30.08.2010. Ørnefotografering med Pål Hermansen. Espen Lie Dahl
Fotografi.no – 12082010. Vinger over Smøla. Espen Lie Dahl
Foto.no – 2206.2010. Nordic Light presenterer: Vinger over høy himmel på Smøla med Pål Hermansen. Espen Lie Dahl
Nordvestnytt - 03.06.2010. Helt konge! Espen Lie Dahl
NRK – 11.05.2010. Rekordmange havørn. Espen Lie Dahl
Statkraft - 23.04.2010. Havørnforskning i Smøla vindpark. Kjetil Bevanger
Energi Norge - 20.04.2010. Vindkraft og fugl på Smøla. Kjetil Bevanger
Statkraft – 18.02.2010. Etterundersøkelser - Hitra vindpark. Kjetil Bevanger
Tidens Krav - 24.12.2009. Fuglelivet på Smøla. Espen Lie Dahl
Nordvestnytt - 16.12.2009. NINA, NOF og havørn - Informasjon eller desinformasjon? Kjetil Bevanger
Tidens Krav - 15.12.2009. NINA, NOF og havørn – informasjon eller desinformasjon? Kjetil Bevanger
Tidens Krav - 14.12.2009. Oppløftende havørn-funn på Smøla. Espen Lie Dahl.
Tidens Krav - 11.12.2009. Oppløftende havørn-funn. Espen Lie Dahl.
AgderAvisen - 09.12.2009. Vindkraftanlegget på Smøla ikke i strid med Bern-konvensjonen. Kjetil Bevanger.
Miljøverndepartementet - 08.12.2009. Vindkraftanlegget på Smøla ikke i strid med Bern-konvensjonen. Kjetil Bevanger
Kraftnytt.no - 08.12.2009. Vindkraftanlegget på Smøla ikke i strid med Bern-konvensjonen. Kjetil Bevanger.
Statkraft - 08.12.2009. Mer aktiv ørn på Smøla. Kjetil Bevanger.
NINA 12.04.2009. Fugleforskningen i Smøla vindpark gir resultater. Espen Lie Dahl.
Andøyposten – 21.11.2009. Norge bryter internasjonal avtale ved etablering av vindindustri. Kjetil Bevanger.

Bladet Vesterålen – 18.11.2009. Norge bryter internasjonal avtale ved etablering av vindindustri. Kjetil Bevanger.

Svenska Dagbladet – 17.111.2009. Nye Vattenfall-vd:n placerade vindkraftpark bland havsörnar. Kjetil Bevanger.

Tidens Krav – 16.11.2009. Sporer fuglefeller. Espen Lie Dahl.

Tidens Krav – 11.11.2009. Workshop Smøla. Espen Lie dahl.

Smøla kommune - 11.11.2009. Nordic light skal jakte havørn på Smøla. Espen Lie Dahl.

12.4 Theses

Dahl, E.L. 2008. Do wind power developments affect breeding biology in white-tailed sea eagle (*Haliaeetus albicilla*)? - Master Thesis, NTNU, Trondheim. 32 pp.

Lund-Hoel, P. 2009. Do wind-power developments affect the behaviour of White-Tailed Sea Eagles on Smøla? - Master Thesis in Ethology, University of Science and Technology (NTNU), Trondheim.

13 References

Ariza, L. M. 1998: The Eagles Have Landed. - New Scientist 157: 25.

Baerwald, E.F., D'Amours, G.H., Klug, B.J. & Barclay, R.M.R. 2008. Barotrauma is a signifi cant cause of bat fatalities at wind turbines. - Current Biology 18: 695-696.

Bakken, V., Runde, O. & Tjørve, E. 2003. Norsk Ringmerkingsatlas. - Stavanger Museum, Stavanger.

Band, W., Madders, M., & Whitfield, D.P. 2007. Developing field and analytical methods to assess avian collision risk at wind farms. - Pp. 259-275 in de Lucas, M., Janss, G.F.E. & Ferrer, M., (eds). Birds and Wind Farms. Risk Assessment and Mitigation. Servicios Informativos Ambientales/Quercus, Madrid.

Barrios, L. & Rodriguez, A. 2007: Spatiotemporal patterns of bird mortality at two wind farms of Southern Spain. - Pp. 229-239 in de Lucas, M., Janss, G. F. E. & Ferrer, M., (eds). Birds and Wind Farms. Risk Assessment and Mitigation. Servicios Informativos Ambientales/Quercus, Madrid.

Bennett, A.T.D., Cuthill, I.C., Partridge, J.C. & Maier, E.J. 1996. Ultraviolet vision and mate choise in zebra finches. – Nature 380: 433-435.

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

Bevanger, K. 1999. Estimating bird mortality caused by collision and electrocution with power lines; a review of methodology. - Pp. 29-56 in Ferrer, M. & Janss, G.F.E.(eds.). Birds and Power Lines: Collision, Electrocution and Breeding. Servicios Informativos Ambientales/Quercus, Madrid.

Bevanger, K., Dahl, E.L., Gjershaug, J.O., Halley, D., Hanssen, F., Nygård, T., Pearson, M., Pedersen, H. C. & Reitan, O. 2010. Ornitologisk etterundersøkelse og konsekvensutredning i tilknytning til planer for utvidelse av Hitra vindkraftverk. - NINA Report 503. Norsk institutt for naturforskning, Trondheim.

Bevanger, K., Berntsen, F., Clausen, S., Dahl, E.L., Flagstad, Ø., Follestad, A., Halley, D., Hanssen, F., E., Hoel, P.L., Johnsen, L., Kvaløy, P., May, R., Nygård, T., Pedersen, H.C., Reitan, O., Steinheim, Y. & Vang, R. 2009. "Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway" (BirdWind). Progress Report 2009. - NINA Report 505. 70 pp.

Bevanger, K., Follestad, A., Halley, D., Hüppop, O., Meese, E., Nygård, T., Pedersen, H.C., Reitan, O., & Pennycuick, C., Wang, D. & Wold, E. 2005. Bird interactions with onshore wind turbines in coastal Norway. - A project proposal to "RENERGI", the Norwegian Research Council, 1 September 2005

Bjerke, J.W., Strann, J., Frivoll, V. & Bergersen, E. 2004. Konsekvensutredning for Andmyran vindpark i Andøy kommune, Nordland – berggrunn, vegetasjon, fugl og annet dyreliv. NINA oppdragsmelding 855. 29 pp.

Bright, J.A., Langston, R.H.W., Bullman, R., Evans, R.J., Gardner, S., Pearce-Higgins, J. & Wilson, E. 2008. Map of bird sensitivities to wind farms in Scotland: a tool to aid planning and conservation. - Biological Conservation 141: 2342–2356.

Brown, A.F. & Shepherd, K.B. 1993. A method for censusing upland breeding waders. - Bird study 40: 189-195.

Buckland, S.T., Anderson, D.R., Burnham, K.P. & Laake J.L. 1993. Distance Sampling: Estimating Abundance of Biological Populations. - Chapman and Hall, New York.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. & Thomas, L. 2001. Introduction to Distance sampling - estimating abundance of biological populations. Oxford University Press, Oxford.

Butler, B.K. 1996. What should I wear while birding? – The Horned Lark, Kansas Ornithological Society.

Cuthill, I.C., Partridge, J.C., Bennett, A.T.D., Church, S.C:, Hart, N.S. & Hunt, S. 2000. Ultraviolet vision in birds. - Adv. Study Behav. 29: 159-214.

de Lucas, M., Janss, G.F.E. & Ferrer, M., (eds.) 2007. Birds and Wind Farms. Risk Assessment and Mitigation. - Servicios Informativos Ambientales/Quercus, Madrid.

Dementavicius, & Treinys, R. 2009. "Nest-site attendance of the resident white-tailed sea eagle (*Haliaeetus albicilla*) outside the breeding season." - Acta Zoologica Lituanica 19: 10-17.

Devereux, C.L., Denny, M.J.H. & Whittingham, M.J. 2008. Minimal effects of wind turbines on the distribution of wintering farmland birds. - Journal of Applied Ecology 45: 1689-1694.

Drewitt, A.L. & Langston, R. 2006. Assessing the impacts of wind farms on birds. - Ibis 148: 2942.

Drewitt, A.L. & Langston, R. 2008. Collision effects of wind-power generators and other obstacles on birds. - Ann. N.Y. Acad. Sci. 1134: 233-266.

Farfan, M.A., Vargas, J.M., Duarte, J. & Real, R. 2009: What is the impact of wind farms on birds? A case study in southern Spain. - Biodiversity and Conservation 18: 3743-3758.

Halley, D.J. & Hopshaug, P. 2007. Breeding and overland flight of red-throated divers *Gavia stellata* at Smøla, Norway, in relation to the Smøla wind farm. - NINA Report 297. 26 pp.

Henderson, I.G., Langston, R.H.W. & Clark, N.A. 1996. "The response of common terns *Sterna hirundo* to power lines: an assessment of risk in relation to breeding commitment, age and wind speed." Biological Conservation 77: 185-192.

Hodos, W. 2003. Minimization of motion smear: reducing avian collisions with wind turbines. - Report NREL/SR-500-33249. National Renewable Energy laboratory, Colorado, USA.

Hoel, P.L. 2009. Do wind power developments affect the behaviour of White Tailed Sea Eagles on Smøla? Master of science thesis. - Department of biotechnology, Norwegian University of Science and Technology, Trondheim, 45 pp.

Ito, H., Sudo-Yamaji, A., Abe, M., Murase, T. & Tsubota, T. 2003. Sex identification by alternative polymerase chain reaction methods in Falconiformes. - Zoological Science 20: 339–344.

Johnsen. L. 2008. Kamerabasert system for overvåking og deteksjon av fugl. Prosjektforslag fra SINTEF IKT, datert 26.08.2008. 6 pp.

Johnsen. L. 2008. Synliggjøring av vindmøller med UV-lys. Prosjektforslag fra SINTEF IKT, datert 29.08.2008. 7 pp.

Kolås, T. & Johnsen, L. 2007. Forslag til tiltak for å unngå at fugler kolliderer med vindturbiner. - Internal Report received by NINA 21.04.2007. SINTEF Project no. 90J287. 27 pp.

Korbel, R.T. 2002. Avian ophthalmology – principles and applications. – http:/www.vin.com.proceedings/Proceedings.plx?CID=WSAVA2002&PID=2644

Kålås, J.A., Viken, Å. & Bakken, T. (eds.). 2006. Norsk Rødliste 2006. Artsdatabanken, Norge.

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

Leddy, K.L., Higgins, K.F., & Naugle, D.E. 1999. Effects of wind turbines on upland nesting birds in conservation reserve program grasslands. - Wilson Bulletin 111: 101-104.

Lendvai, A.Z., Kis, J., Szekely, T. & Cuthill, I.C. 2004. An investigation of mate choice based on manipulation of multiple ornaments in the Kentish plover. - Animal Behaviour 67: 703 - 709.

Lyne, K., Gassner, I., Bolger, R.& Kelly, T.C. 1998. Is there a bird strike syndrome?: Preliminary results from autopsy findings. - Proceedings of the 24th International Bird Strike Committee; 97-123.

Manly, B.F.J. 1997. Randomization, bootstrap and Monte Carlo methods in biology. - Chapman & Hall/CRC, Bocca Raton, Florida.

Martin, G. 1990. Birds by night. - London: Poyser.

May, R., Hoel, P.L., Langston, R., Dahl, E.L., Bevanger, K., Reitan, O., Nygård, T., Pedersen, H.C., Røskaft, E. & Stokke, B.G. 2010. Collision risk in white-tailed eagles. Modelling collision risk using vantage point observations in Smøla wind-power plant. – NINA Report 639. 25 pp.

May, R. & Nygård, T. 2009: Spatial assessment of white-tailed sea eagle collision risk at the onshore wind-power plant on the island of Smøla. - 2nd European Congress of Conservation Biology. Conservation biology and beyond: from science to practice. Czech University of Life Sciences, Prague.

McIlwain, J. T. 1996. An introduction to the biology of vision. – Cambridge University Press.

Meese, E.A. 2008. Aerodynamics of wind-power plants and impact on bird behaviour – suggestion for activity. - Prosjektforslag fra SINTEF Materials and Chemistry, datert 12.9.2008. 2 pp.

Mojica, E. K., Watts, B.D., Paul, J.T. Voss, S.T. & Pottie, J. 2009: Factors Contributing to Bald Eagle Electrocutions and Line Collisions on Aberdeen Proving Ground, Maryland. - Journal of Raptor Research 43: 57-61.

Oehme, G. 2003. On the methods, terminology and criteria in population studies of the white-tailed eagle. - Pp. 25-27 in B. Helander, Marquiss, M. & Bowerman, W. (eds.). Sea Eagle 2000. Proceedings from the international sea eagle conference in Björkö, Sweden, 13-17 September 2000.

Pearce-Higgins, J.W. & Yalden, D.W. 2005. Difficulties of counting breeding golden plovers *Pluvialis apricaria.* - Bird Study 52: 339-342.

Pearce-Higgins, J.W., Stephen L., Langston R.H.W., & Bullman, R. 2009. The distribution of breeding birds around upland wind farms. - Journal of Applied Ecology 46: 1323–1331.

Ponce, C., Alonso, J. C., Argandona, G., Fernandez, A. G. & Carrasco, M. 2010.Carcass removal by scavengers and search accuracy affect bird mortality estimates at power lines. Animal Conservation 13: 603-612.

Rollan, A., Real, J. Bosch, R., Tinto, A. & Hernandez-Matias, A. 2010. Modelling the risk of collision with power lines in Bonelli's Eagle Hieraaetus fasciatus and its conservation implications. - Bird Conservation International 20: 279-294.

Ruxton, G.D. & Colegrave, N. 2006. Experimental design for the life sciences. Second edition. - Oxford University Press, Oxford. 162 pp.

Siitari, H. & Huhta, E. 2002. Individual color variation and male quality in pied flycatchers (*Ficedula hypoleuca*): a role of ultravioloet reflectance. – Behaviioural Ecology 13: 737-741.

Smallwood, K.S. 2007. Estimating wind-turbine caused bird mortality. - Journal of Wildlife Management 71: 1513-1524.

Smallwood, K.S. & Thelander, C. 2008: Bird mortality in the Altamont Pass Wind Resource Area, California. - Journal of Wildlife Management 72: 215-223.

Smallwood, K.S., Bell, D.A., Snyder, S.A. & Didonato, J.E. 2010. Novel Scavenger Removal Trials Increase Wind Turbine-Caused Avian Fatality Estimates. - Journal of Wildlife Management 74: 1089-1097.

Smith, E.L., Greenwood, V.J., Goldsmith, A.R. & Cuthill, I.C. 2005. Effect of supplementary ultraviolet lighting on the behaviour and corticosterone levels of Japanese quail chicks. - Animal Welfare 14: 103 - 109.

Stewart, G.B., Pullin, A.S. & Coles, C.F. 2007. Poor evidence-base for assessment of windfarm impacts on birds. Environmental Conservation 34: 1-11.

Thielman,J. 2008. Fugler og vindmøller fase III. Prosjektforslag fra SINTEF IKT, datert - 27.082008. 9 pp.

Toke, D., Breuker, S. & Wolsink, M. 2008. Wind power deployment outcomes: How can we account for the differences? - Renewable and Sustainable Energy Reviews 12: 1129–1147.

Tømmeraas, P.J. 1989. Carrion feeding in the Gyrfalcon Falco rusticolus: a review. - Fauna norvegica Serie C, Cinclus 12: 65-77.

Tømmeraas, P.J. 2004. Jaktfalk på Nordkalotten. - Våre Rovdyr 18: 36-47.

Tømmeraas, P.J. 2006. Jaktfalk *Falco rusticolus* Gyr Falcon. - P. 166 in Svorkmo-Lundberg, T., Bakken, V., Helberg, M., Mork, K., Røer, J.E., & Sæbø, S. (eds). Norsk VinterfuglAtlas. Fuglenes utbredelse, bestandsstørrelse og økologi vinterstid. - Norsk Ornitologisk Forening, Trondheim.

Valberg, A. 1998. Lys, syn,farge. – Tapir Forlag, Trondheim.

Whitfield, D.P. 2009. Collision Avoidance of Golden Eagles at Wind Farms under the ‘Band’ Collision Risk Model. -. Natural Research, Ltd., Banchory, UK, 35 pp.

Worton, B.J. 1989: Kernel methods for estimating the utilization distribution in home-range studies. - Ecology 70: 164-168.

Young, D.P.Jr., Erickson, W.P., Strickland, M.D. Good, R.E. & Sernka, K.J. 2003. Comparison of avian responses to UV-light-reflective paint on wind turbines. - Report NREL/SR-500-3284. National Renewable Energy laboratory, Colorado, USA.

14 Appendices

Appendix 1. *Brief history of the research activities coordinated by NINA in connection to the Smøla Wind-power plant.*

1999:
NINA asked by Statkraft to carry out an EIA for the planned Smøla Wind-power plant, focusing red-listed species (based on existing knowledge).

1999:
The NINA EIA report finalised: ”*Wind mill park at Smøla: Potential impacts on bird species on the Norwegian red list*” (NINA Oppdragsmelding 623).

Main conclusions:
“A wind-power plant on Smøla will affect a breeding population of 50-60 white-tailed eagle (WTE) pairs, i.e. an area with the most abundant WTE population in Norway. Available data indicate that the WTE breeding on Smøla to a minor extent locate their nests closer to areas with human activities or infrastructure (i.e. roads, houses, holyday houses etc.) than 1000 m. Depending on the selected alternatives for the wind turbine siting and number, the following direct effects are supposed to occur:

- *Alternative 1-4 (40 MW, A, B, C, Phase 1): A minimum of 4-5 pair are supposed to be affected so heavily that they will abandon the area as a breeding ground. The A, B and C alternatives will partly affect different pairs, however, the number of pairs affected seems to be the same.*
- *Alternative 150 MW: 9-10 pairs are supposed to be affected so heavily that they will abandon the power plant area as a breeding ground.*

It is difficult to assess the long-term consequences for the WTE population of this, as we among other things do not know what will happen if the pairs abandon their traditional breeding grounds and try to settle outside the power plant area, as most of the optimal habitats already are “saturated” with WTE. However, depending on age, social structure etc. it may result in a long term noise in the population before new territories and new migrating corridors between these and the hunting areas in the marine habitats are re-established. This might in the short term also lead to lowered nesting success for a major part of the population and in the long term to a permanent reduction of the WTE population on Smøla (and the north-western parts of the western coastal region).”

2002:
NINA asked by Statkraft to ”*Prepare a program for post-construction studies*”, ”*Spring censuses of Smøla Willow Ptarmigan*" and ”*Assessment of ornithological consequences given a lay-out change of Smøla Wind-power plant Phase II*”.

2003:
NINA asked by Statkraft to carry out ”*Population monitoring of WTE on Smøla in 2003 related to the wind-power plant*” and make a “*Proposal for additional data collection: Recording of WTE killed due to collisions with wind turbines*”.

2004:
NINA applied for money to the Norwegian Water Resources and Energy Directorate (NVE) and the research activities related to WTE were continued within a funding consortium by NVE, Statkraft, the Norwegian Electricity Industry Association (EBL) and Norsk Hydro. The activities were denoted ”*Wind Power and Birds; Research and Development Project 2004*”.

2005:

The research activities related to the WTE were funded by NVE, the Directorate for Nature Management (DN), EBL and Statkraft, and denoted "*Support for research on wind power and birds*".

2006:

The research activities related to WTE were discussed in a meeting at the NVE Head Office in Oslo on March 22, and economic support was agreed on, following the 2004 and 2005 model. In April several dead WTEs were recorded within the wind-power plant area, and Statkraft invited NINA to a meeting at the Statkraft Head Office in Oslo May 9, asking to prepare for a larger research project, including experiments on mitigating measures.

It was agreed that NINA, together with SINTEF, should prepare an outline pilot project proposal. The outline proposal, with economic framework, was sent to Statkraft on 20th June 2006. On the basis of verbal agreements, the following activities in the pilot project were begun:

- Regular searches for dead birds within the wind-power plant area assisted by specially trained dogs
- Video monitoring of WTE behaviour
- Genetic analyses of feathers from WTE on Smøla

Activities related to population monitoring and behaviour of WTE were carried out in 2006, based on funding from NVE, Statkraft, and RSPB.

In June 2006 NINA submitted an application (9.135 mill. NOK) for the period 2007-2010, to the Research Council of Norway (NFR) named "*Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway*" (a socalled KMB, i.e. a capacity-building project with industry/user participation). NVE, Statkraft and EBL agreed to contribute supplementary funds (2.365 mill. NOK) during the project period. In the application it was established as a basis that the activities initiated and financed by Statkraft in 2006, would be continued through the project period. This in particular concerned the purchase of radar equipment and development of other technical tools to test possible methods to prevent bird strikes. The budget in the NFR project was in consequence very tightly precommitted, and it was a precondition that the research advances would come from activities financed on the basis of resources from the NFR project together with additional resources from Statkraft and possible other actors like NVE, EBL, and DN/MD. In late December 2006 it was confirmed that the project had received financing from the RENERGI Programme.

2007

On a meeting in Trondheim at the NINA Head Office January 4 2007, with Statkraft, SINTEF and NINA present, the short- and long-term activities and funding of the project were discussed. The meeting concluded, among other things, that Statkraft would fund a pilot study focusing the advantages/disadvantages of avian radar technology, together with possible technical solutions which might be useful for basic data recording, involving audio and visual stimuli. This work was primarily carried out by SINTEF and the final reports from SINTEF were sent to Statkraft on 24th April 2007. On the 15th of May 2007 NINA sent a note to Statkraft where, *inter alia,* an economic guarantee was requested to obtain a radar in accordance with the recommendation of the SINTEF report. In June 2007 NINA and Statkraft signed an agreement (Contract 45000022770) that Statkraft should contribute with 9.610 mill NOK within the project period (2007-2010). The funding was earmarked activities described in the agreement document.

2008:

NINA signed a contract with DeTect and received in March a Merlin avian radar. In spring 2008 NINA was invited by NFR to apply for extra funding for the project and received in September an extra grant of 1.5 mill. NOK for "*Data flow and storing, visualisation and modelling*". Statkraft promised another 1 mill. NOK for support to the avian radar research activities.

2009:
In late 2008 and early 2009 Statkraft and NINA discussed the possibilities to raise money for a PhD student to model the future WTE population development based on reproduction and mortality data. An agreement was signed where the total costs of 2.5 mill. NOK were divided between NINA and Statkraft with 1 and 1.5 mill. NOK respectively. The position is held for four years (2009-2012).

In spring 2009 the project was integrated in CEDREN – i.e. the *Centre for environmental design of renewable energy*. CEDREN is one of 8 centres for Environment-friendly Energy Research (CEER) in Norway. The establishment of the CEER scheme is a direct response to the broad-based agreement on Norway's climate policy in the Norwegian Parliament (Stortinget), reached early in 2008, and the adoption of the national R&D strategy *Energi21.* Norway has decided to earmark at least 100 million NOK per year to the CEER initiative. For the Norwegian research institutions the application process started in May 2008 and a final decision on the winners was taken by the Research Council Executive Board on 28 January 2009, and the official announcement was made by the Minister of Oil and Energy February 4 2009. CEDREN is a consortium with SINTEF, NTNU and NINA as key institutions. SINTEF is responsible for coordinating the CEDREN activities and the basic funding comes from NFR, together with users like Statkraft, EBL, NVE etc. Thus the basic activities within CEDREN are based on the ongoing activities in BirdWind and 6 other KMB projects. The overall objective of CEDREN is to *develop and disseminate effective design solutions for renewable energy production that take adequate account of environmental and societal issues, both locally and globally*.

Appendix 2. *Program for the BirdWind Annual Meeting on Smøla 2010*.

THE BIRDWIND ANNUAL MEETING ON SMØLA - MARCH 22-23 2010

The BirdWind (”*Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway*”) project is approaching its final stage, and the last annual meeting takes place at Havfiskesenteret on Smøla 22-23 March 2010. The meeting is an arena where the involved scientists and representatives from the funding institutions meet, i.e. the Norwegian Research Council, Statkraft, EnergiNorge, NVE and DN. On Monday we will focus on the scientific topics covered by the project, while we intend to use the two hours available on Tuesday for a discussion on future research needs. Short introductions to the discussion will be made by representatives from NINA, Statkraft, NVE and DN. NINA will focus on new research initiatives on ecosystem impacts of off-shore wind power development, while Statkraft will have a look at the possibilities for, and the content of, a “BirdWind II”. The energy and environmental management authorities - NVE and DN - are facing several challenges with respect to the future plans for wind power development both off-shore and on-shore. Topics for discussion will be on cumulative effects, criteria, prioritizing and site selection of future wind-power plants, as well as possible follow-up issues from the Bern Convention Recommendations.

Monday 22 March

1145-1230	Lunch at Havfiskesenteret	
1230-1255	Welcome and status remarks (Kjetil Bevanger)	
1300-1430	White tailed eagle studies – status and the road ahead	
	1300-1325	Telemetry and risk assessment (Torgeir Nygård)
	1330-1355	Genetic analyses (Øystein Flagstad)
	1400-1425	Population monitoring and modelling (Espen Lie-Dahl)
1430-1450	Coffee	
1450-1600	Camera monitoring	
	1450-1500	Biological rationale for a camera monitoring system (Kjetil Bevanger)

1500-1525 Hardware and software constraints (Lars Johnsen)
1530-1555 Alternative solutions for camera monitoring (Akkadia/Astraguard)
1600-1615 Short break with coffee
1615-1730 Radar studies
1615-1635 Status, clutter modelling and data mining (Roel May)
1640-1700 Detection constraints and target tests (Yngve Steinheim)
1705-1725 A consensus paper on radar ornithology (Mark Desholm)
1730-1800 Mortality studies – status and methodological challenges (Ole Reitan)
1800-1820 Willow ptarmigan studies (Hans Chr. Pedersen)
1900 Dinner and social

Tuesday 23 March
0800-0900 Breakfast
0900-1100 Future plans/needs for ecological research in connection to wind energy development. Short introductions by

- NINA/CEDREN
- Statkraft
- NVE
- DN

1100-1145 Lunch
1145 Departure

Some changes to the program may take place. Please report back as soon as possible (at the latest on March 10) due to confirmation needs for accommodation facilities. Due to limited capacity we normally have a 3 person limit for each institution; however, we are flexible regarding this.

Participants:

Auran, Jo Anders (DN)
Bevanger, Kjetil (NINA)
Bjugan, Lars Håkon (NVE)
Breistein, Dag (Vestavind Offshore)
Desholm, Mark (DMU)
Elgersma, Trine (Statkraft)
Flagstad, Øystein (NINA)
Follestad, Arne (NINA)
Halley, Duncan (NINA)
Hanssen, Frank (NINA)
Iuell, Bjørn (Statkraft)
Johnsen, Lars (SINTEF)
Kvaløy, Pål (NINA)
Langston, Rowena (RSPB)
Lie-Dahl, Espen (NINA)
May, Roel (NINA)
Nygård, Torgeir (NINA)
Pedersen, Hans Chr. (NINA)
Reitan, Ole (NINA)
Røstad, Håvard (NVE)
Schei, Tormod (Statkraft)
Soleim, Arild (Statkraft)
Steinheim, Yngve (SINTEF)
Stenseth, Rune (Akkadia)
Vang, Roald (NINA)
Wilhelmsen, Einar (EnergiNorge)

Practical information:
Accommodation at Havfiskesenterert. Those arriving from Trondheim will take the speedboat at 0800 Monday morning, arriving on Smøla (Edøy) at 1050. Transport by bus to Havfiskesenteret. It is also possible to take an aircraft to Kristiansund and car/speedboat from there. We will leave Havfiskesenteret at 1145 on Tuesday and reach the speedboat to Trondheim, departing from Edøy at 1240 – arriving Trondheim 1535.

NINA Report 620

ISSN: 1504-3312
ISBN: 978-82-426-2198-6

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

www.nina.no

Graphic design: NINA
Cover photos: Per Jordhøy, Børre Dervo,
Knut Kringstad, Tycho Anker-Nilssen