NINA Report 409

"Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway"

Progress Report 2008

Kjetil Bevanger, Stig Clausen, Espen Lie Dahl, Øystein Flagstad, Arne Follestad, Jan Ove Gjershaug, Duncan Halley, Frank Hanssen, Pernille Lund Hoel, Karl-Otto Jacobsen, Lars Johnsen, Roel May, Torgeir Nygård, Hans Christian Pedersen, Ole Reitan, Yngve Steinheim, Roald Vang

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Norwegian Institute for Nature Research

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COVER PICTURE
Bird radar operating in the Smøla wind-power plant. Photo: Kjetil Bevanger

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Abstract

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.

The NFR-funded project *Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway* is about to end its second year of activities, and as such it has reached a stage of intensive fieldwork and data collection. Monitoring of bird mortality within the wind power plant area takes place on a weekly basis assisted by special trained dogs. So far in 2008 (as of December 1) 9 white-tailed sea eagles (WTSE) and 7 willow ptarmigans have been recorded. Another 4 common snipes, 2 hooded crow, 2 golden plovers, 2 greylag goose, one grey heron, one kittiwake, one herring/greater black-backed gull, one merlin and one redshank have been collected; i.e. a total of 31 victims so far in 2008. The willow ptarmigan population have been monitored in spring and autumn and 6 willow ptarmigans were trapped and radio-tagged (in January-March). The trapping efforts have now been resumed and another 8 birds have been radio-tagged (up to December 1). A new activity on eagle owl, funded by the Directorate for Nature Management, is included in the project. The objectives with this project are, among other things, to collect mortality data using radio telemetry. However additional funding is needed. With respect to waders and smaller passerines the field work in 2008 was performed at a planned wind power plant site in Northern Norway, Andøya, to document the breeding bird status prior to the construction. The project still concentrates heavily on WTSE research, and this summer another 9 nestlings were equipped with radio transmitters, of which 3 have quit transmitting. Feather samples for DNA-analyses are collected, and when the samples of 6 WTSE adult collision victims recorded in 2008 were compared to 2006/2007 samples, it turned out that they matched two territorial birds with territories approximately 1.5 and 8 km from the wind power plant, respectively. A Master Thesis at the University of Science and Technology in Trondheim (NTNU) focusing possible effects of the wind power plant on WTSE nesting success was concluded in September. One of the conclusions was that territories within or close to the power plant had a lowered nesting success after construction, compared with the same territories before construction. Another master student has collected data on WTSE behaviour inside and outside the wind power plant area to identify possible turbine generated differences in behaviour. These data are now being processed and the Thesis will be finalized in spring 2009. An important incident this year was the procurement of a bird radar lab. After some trial and error with respect to siting within the power plant area, the radar has now been collecting data continuously since April 3. Data processing is now under way. To investigate MERLIN radar performance at its current location field trials with dedicated controlled targets have been performed using model aircraft. 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. In connection to turbine 43 a total of 6 daylight and one IR camera have been installed to monitor bird flight behaviour close to the turbines and to learn more about how turbine generated turbulence may affect the bird's ability to manoeuvre in the air. Another objective is to evaluate possible "early warning devices" and mitigating measures when birds get at a critical distance to a turbine. A significant effort has been put into the construction of functional operational systems for broadband transmission of data from the radar and camera systems on Smøla to NINA HQ in Trondheim. This is now in place and adequate storing and retrieving systems is being focused. Another effort is connected to developing a system for gathering all MERLIN GIS tools to be used in ArcGIS desktop 9.x. and also to develop tools for analysing collision tracks in ArcGIS desktop. An important task is the ongoing terrain modelling inside and outside the power plant area together with the ground clutter modelling and radar-coverage at different altitudes from the current MERLIN radar location. Finally we have developed a dynamic literature database (usind EndNote Web) for publications on birds and wind energy and related topics.

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Sammendrag

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 Rapport 409. 55 s.

NFR-prosjektet *Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway* er snart 2 år gammelt og inne i en periode hvor feltarbeid og datainnsamling står i fokus. Overvåking av dødelighet hos fugl i vindkraftverkområdet skjer gjennom ukentlige søk sammen med spesialtrente hunder, og så langt (pr. 1. desember) er det inneværende år funnet 9 døde havørner og 7 liryper. I tillegg er det funnet 4 enkeltbekkasiner, 2 kråker, 2 heiloer, 2 grågjess, en gråhegre, en krykkje, en ubestemt gråmåke/svartbak, en dvergfalk og rødstilk, i alt 31 fugler. Det er utført takseringer av rypebestanden vår og høst i tillegg til at 6 ryper ble fanget (i perioden januar-mars) og påsatt radiosender. Fangst og radiomerking er nå gjenopptatt og pr. dags dato (1. desember) er 8 nye ryper radiomerket. Et nytt prosjekt på hubro, finansiert av Direktoratet for naturforvaltning, er tatt inn under hovedprosjektet. Målsettingen er å få et bedre bilde av artens viktigste dødsårsaker ved hjelp av radiotelemetri, men ytterligere finansiering er nødvendig. I forhold til vadere og mindre spurvefugl er det inneværende år foretatt bestandstaksering i et planlagt utbyggingsområde for vindkraft på Andøya, slik at førsituasjonen er dokumentert. Det er fremdeles betydelig fokus på havørn, og 9 reirunger er påsatt radiosendere inneværende år, hvorav 3 har sluttet å sende. Det er samlet fjærprøver for DNA-analyse, og da prøver fra 6 kollisjonsdrepte, voksne ørner funnet i 2008 ble sammenlignet med fjærprøver innsamlet i 2006/2007, viste de seg å tilhøre territorielle fugler med territorier henholdsvis ca. 1,5 og 8 km fra vindkraftverket. En masteroppgave ved NTNU som har fokusert på om det kunne spores effekter av vindkraftverket på hekkesuksess hos havørn ble avsluttet i september, og konkluderte bl.a. med at territorier innenfor, eller nært opp til vindkraftverket, i perioden etter utbygging hadde en lavere hekkesuksess sammenlignet med de samme territoriene før utbygging. En annen mastergradsstudent har samlet data på adferd hos havørn i og utenfor vindkraftverket for eventuelt å se om ørnenes adferd påvirkes av turbinene. Disse dataene er nå under bearbeiding og vil bli ferdigstilt i løpet av våren 2009. En viktig hendelse inneværende år er at en spesialtilpasset radar for å observere fugler er kommet på plass. Etter en oppstartsperiode med utprøving av ulike oppstallingsplasser har radaren siden 3. april stått og samlet data kontinuerlig på samme sted. Bearbeiding av data er nå igangsatt. Det er også utført tester (v.hj.a. modellfly) for bl.a. å se om de radarinnstillingene som nå benyttes bør justeres i forhold ønsket deteksjonsnivå. Ved turbin 43 er spesialkonstruerte oppsett for 6 dagslys og ett IR kamera installert. Formålet med dette er bl.a. å lære mer om adferden hos fugler nært opp til turbinene; bl.a. hvorvidt turbulens bidrar til å påvirke fuglenes manøvreringsevne. Et annet aspekt er å se om det kan la seg gjøre å utvikle varslingssystemer og avbøtende tiltak når fugler kommer i kritiske avstander til turbinene. I løpet av året er det også lagt ned et stort arbeid i å få funksjonelle operative systemer for bredbåndsoverføring av data fra radar- og kamerasystemene på Smøla til NINA i Trondheim. Dette er nå på plass og det arbeides videre med adekvate lagringssystemer. Arbeidet med å utvikle et system for å samle alle GIS-verktøyene tilknyttet den spesialutviklede programvaren i radaren (MERLIN) slik at dette kan brukes i ArcGIS desktop 9.x, pågår. Det er også igangsatt er utviklingsarbeid for å analystere potensielle "kollisjonsspor" i ArcGIS desktop. Et annet viktig arbeid er terrengmodelleringen av området i og utenfor vindkraftverket samt modellering av clutter og radardekning i ulike høydenivå. En dynamisk database (EndNote Web) for vindkraftlitteratur er utviklet på oppdrag fra NVE.

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Contents

Foreword

From 2007 inclusive, NINA has received economic support for research on wind power and birds from the Norwegian Research Council (NFR) through the RENERGI-programme. The project is named *Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway*. It is a capacity building project with user participation (KMB). The project has a comprehensive and challenging goal framework, as much economic as scientific, and can only be carried out through a close cooperation with the central energy and environmental management together with the wind-power plant owners. In addition to the Norwegian Water Resources and Energy Directorate (NVE), the Norwegian Electricity Industry Association (EBL), and Statkraft at the outset committed themselves to contribute with an annual economic support to the project (at least 20% of the total costs). Additionally Statkraft guaranteed a considerable economic support for, among other things, the purchase of a bird radar system which became operative in March 2008. In the course of 2007 and 2008, the environmental management authorities (MD and DN) and NVE have contributed economically both to existing and new research modules under the umbrella of the project. In spring 2008 NINA was invited by NFR to apply for extra funding for the project and received in September an extra grant of NOK 1.5 mill. for purchase of additional ICT equipment.

Trondheim, 1 December 2008

Kjetil Bevanger
Project leader

1 Introduction

Since 1999 NINA has carried out research and review activities related to wind power and birds (with special focus on white-tailed sea eagles). The basic funding has come from NVE and Statkraft, but also from EBL, DN/MD, Norsk Hydro, RSPB and AMEC (Follestad et al. 2007, Bevanger et al. 2008).

In December 2006 NINA received funding from NFR on the project application *"Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway"* (within the RENERGI Programme). The project activities up to January 2008 is summarised by Bevanger et al. (2008), and this report briefly summarises the activities in 2008.

All subprojects are now in progress although some are lagging behind the original schedule. This relates particularly to the avian radar subproject. Some new projects have been included in 2008 under the project umbrella; e.g. one focusing eagle owl. NFR invited some of the ongoing projects within the RENERGI Programme to apply for extra funding in spring 2008, and in September NINA got the message that this project was given NOK 1.5 mill. for purchase of additional ICT equipment. NFR has also supported an application from NINA to prolong the project period by one year; i.e. up to December 31 2011.

2 Project meetings

A two day meeting was organised on Smøla also in 2008. The following persons participated: **NINA**: Kjetil Bevanger, Espen Lie Dahl, Arne Follestad, Duncan Halley, Pernille Lund Hoel, Roel May, Torgeir Nygård, Hans Christian Pedersen, Ole Reitan. **SINTEF**: Lars Johnsen, Yngve Steinheim. **University of Uppsala**: Olle Håstad. **RSPB**: Rowena Langston; **NVE**: Nils Henrik Johnson, Håkon Bjugan. **DeTect**: Andreas Smith.

Mark Desholm (NERI – The National Environmental Research Institute, Denmark), Harald Rikheim (NFR) and Tormod Schei (Statkraft) was not able to attend the meeting. No representative from EBL was present.

As the avian radar MERLIN had arrived only few days ahead of the meeting, a representative from the radar constructing company (DeTect) was present. He (Andreas Smith) gave a talk on the main radar principles, and the participants had the opportunity to se how the radar was operated in practice. The only financing institution present at the meeting was NVE. A status report on the different subprojects was presented by the subproject responsible person (the presentations are listed in section 4.2).

A one day meeting was organised at NINA in Trondheim on November 28. The following persons participated: **NINA**: Kjetil Bevanger, Stig Clausen, Espen Lie Dahl, Arne Follestad, Jan Ove Gjershaug, Frank Hanssen, Pernille Lund Hoel, Roel may, Torgeir Nygård, Hans Christian Pedersen, Ole Reitan. **SINTEF:** Yngve Steinheim. **NVE**: Nils Henrik Johnson, Håkon Bjugan. **DN**: Arild Espelien, Odd Kristian Selboe, Frank Johansen. **EBL**: Einar Wilhelmsen. **Statkraft**: Arild Soleim.

Mark Desholm (NERI – The National Environmental Research Institute, Denmark), Rowena Langston (RSPB), Olle Håstad (Univ. Uppsala), Harald Rikheim (NFR) and Tormod Schei (Statkraft) were not able to attend the meeting. From NINA and SINTEF Øystein Flagstad, Roald Vang, Duncan Halley and Lars Johnsen were absent.

A status report on the different subprojects was presented by the subproject responsible person (the presentations are listed in section 4.2) followed by constructive discussions.

3 Status of individual subprojects

3.1 Mortality studies

Subproject responsibility: Ole Reitan

Objective: To conduct regular searches for dead birds in the wind power plant area as a basis for estimating species-specific collision risks.

Weekly searches with dogs have been carried out throughout the year, with a few exceptions (week no. 14, 27, 34, 42, 48). In general searches are conducted every 7 days (plus or minus one day). 25 ‘primary turbines’ are selected and searched together with one of two dogs. Of these 17 were defined as ‘outer turbines’, and 8 as ‘inner turbines’. The other turbines are searched using a dog in selected weeks in periods with high bird activity. In addition all turbine locations were searched visually on each search day. The scavenger removal bias has been estimated based on artificially carcasses placed at randomly selected wind turbines, in randomly selected distances and compass directions from the turbines (week 31). Visual searches were done during all car-driving along roads and turbine locations.

Table 1. *Remaining carcasses within 100 m from wind turbine in the 2008-experiment. N=10 in each experiment.*

Experiment	Date of start	Week 1	Week 2	Week 4
2008-1	30 July 2008	90%	90%	80%
2008-2	30 July 2008	100%	100%[1]	90%[1]

[1] 2 carcasses moved 12 and 6 m, respectively

In 2008 (up to December 1) 31 specimens of at least 11 species have been recorded. The most frequent victims were willow grouse and sea eagles with 7 and 9 carcasses respectively. Of waders 4 common snipes, 2 golden plovers and 1 redshank were recorded. Two carcasses were recorded of greylag goose and hooded crow, and single carcasses of grey heron, kittiwake, herring/greater black-backed gull, and merlin. In 2008 more sea eagles and wetland birds were found compared to 2007, but less ptarmigans (figure 1). 66 of the 82 victims were found during searches with a dog.

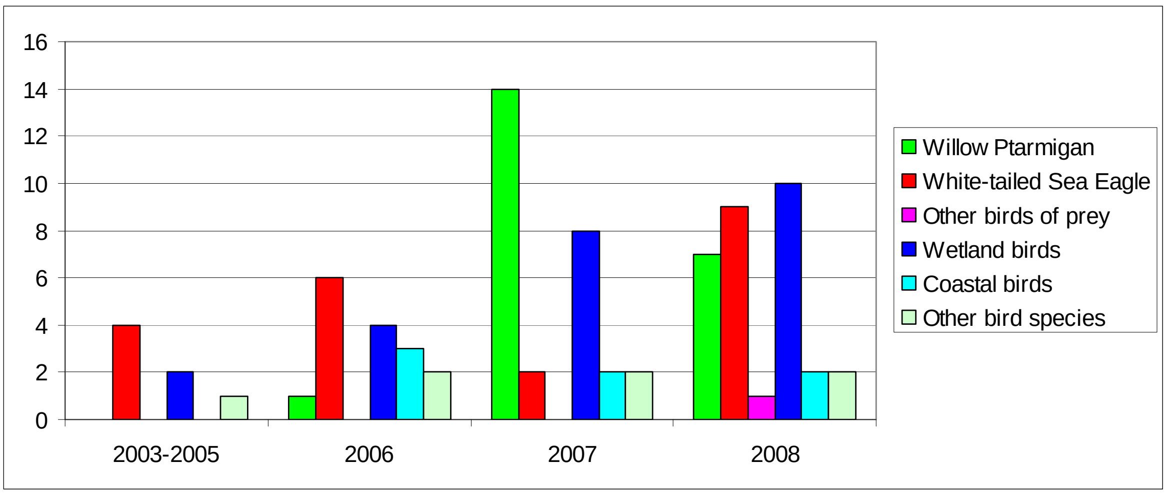

Figure 1. *Bird collision victims recorded close to the wind turbines at Smøla wind power plant. “Other birds of prey” is a merlin; “wetland birds” are waders, ducks, geese, swans and grey heron; “coastal birds” are gulls, auks, and fulmar and “other bird species” are passerines.*

On average, approximately 10% of the dead birds disappear every week, but bird remains can remain for quite some time (table 1). Search effectiveness lies between 0.3 and 0.8 for the specially trained dog, and 0.4-0.6 for the generally trained dog. Activities in 2009 will be as for 2008.

Figure 2. *Espen Lie Dahl with a dead white-tailed sea eagle recorded beneath turbine 67 (March 13 2008). Photo: Kjetil Bevanger.*

Table 2. *Birds recorded as collision victims in connection to the wind turbines on Smøla, until 1 December 2008.*

Species	Scientific name	2003-2005	2006	2007	2008	Total
Willow ptarmigan	*Lagopus lagopus*		1	14	7	22
White-tailed sea eagle	*Haliaeetus albicilla*	4	6	2	9	21
Common snipe	*Gallinago gallinago*		1	3	4	8
Gulls	*Larus* spp.		3		2	5
Hooded crow	*Corvus cornix*	1	1		2	4
Golden plover	*Pluvialis apricaria*			2	2	4
Grey heron	*Ardea cinerea*	1	1		1	3
Greylag goose	*Anser anser*	1			2	3
Whooper swan	*Cygnus cygnus*		1			1
Mallard	*Anas platyrhynchos*			1		1
Teal	*Anas crecca*			1		1
Shoveler	*Anas clypeata*		1			1
Red-breasted merganser	*Mergus serrator*			1		1
Merlin	*Falco columbarius*				1	1
Northern fulmar	*Fulmarus glacialis*			1		1
Little auk	*Alle alle*			1		1
Redshank	*Tringa totanus*				1	1
Meadow pipit	*Anthus pratensis*			1		1
Fieldfare	*Turdus pilaris*		1			1
Bird indet.				1		1
Birds total		7	16	28	31	82

Figure 3. *Ole Reitan summarizing the bird mortality subproject at the Smøla Meeting 2008*. *Photo: Kjetil Bevanger.*

3.2 Willow ptarmigan

Subproject responsibility: Hans Chr. Pedersen

Objectives: 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.

In connection to the Environmental Impact Assessment before the development of the wind power plant on Smøla, 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 (Solvang et al. 2005). From spring 2007 the willow ptarmigan population has been censused spring and autumn in the wind power plant area and in an adjacent control area outside the plant area. The census method used is line transects applying the programme DISTANCE. The census gives information on density and reproduction (chick production) in both areas. Also in 2008 a census has been carried out in spring and autumn in both areas, but compared to earlier years, the number of transect lines has been increased to give more reliable results.

The preliminary results do not indicate any obvious differences between the two areas, but autumn density in the wind power plant area seems to be stable, whereas the density in the control area has decreased during the period 2005-2008 (figure 4). 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 from 2005-

2007 and cannot explain the increasing difference in density between the two areas (figure 5). However, in August 2008 the chick production in the wind power plant area was 6.4 chicks/female and only 2.7 in the control area.

In August 2007 censuses of willow ptarmigan were also carried out on the adjacent island Hitra, in the Eldsfjellet wind power plant, and in the control area Skårfjellet. In both areas suitable willow ptarmigan habitat is very limited and a modified version of DISTANCE was therefore used. The data is too limited to carry out any statistical tests of density differences, but the density in both areas was reduced from 2007 to 2008 (figure 6).

To collect data on habitat selection, movements, collision risks, survival of eggs, chicks and adults and general population dynamic parameters, willow ptarmigan have been radio-tagged in 2008. We have used traditional VHF-transmitters with mortality switch, necklace mount, 12 g Holohill transmitters, lasting approximately 24 months. Due to low population density and only occasional snow cover, a method using strong lights, dipnet and car was used to catch birds. This method can only be used during winter at nights without any moonlight. It is very time consuming, but it works. However, the number of individuals being caught is only 6 in approximately 3 weeks, which is very low.

From 10 January to 10 March 6 birds - 5 females and 1 male - were caught inside the wind power plant area. No trapping was carried out in the control area, mainly due to missing roads. The birds were radio-tracked at irregular intervals and all birds, when found, were within the wind power plant area, not far from where they were caught. At the end of February, no signal was received from a female caught January 10. As this bird was equipped with an old transmitter, an exhausted battery was the likely reason for a missing signal.

The other birds were more or less found in their respective tagging-area during late winter and spring. In late May – early July some of the birds were often missing when ground-tracking. In mid-July an aerial tracking was carried out and all the birds were found within the wind power plant area. However, in late August, one of the remaining females was dead, as only the radio transmitter was found. There were no remains from the female so cause of mortality was impossible to assess. In mid-November only two of the birds were found inside the wind power plant area, and two were missing. Another 8 willow ptarmigans have been radio-tagged in late November/early December (up to December 1).

As yet we have too little data to make any firm conclusions from the radio-tracking study. However, none of the birds have been shown to leave the wind power plant area after being radiotagged. The birds have shown very high site tenacity throughout almost one year. None of the radiotagged birds have been recoded as collision victims in connection to the wind turbines or power lines.

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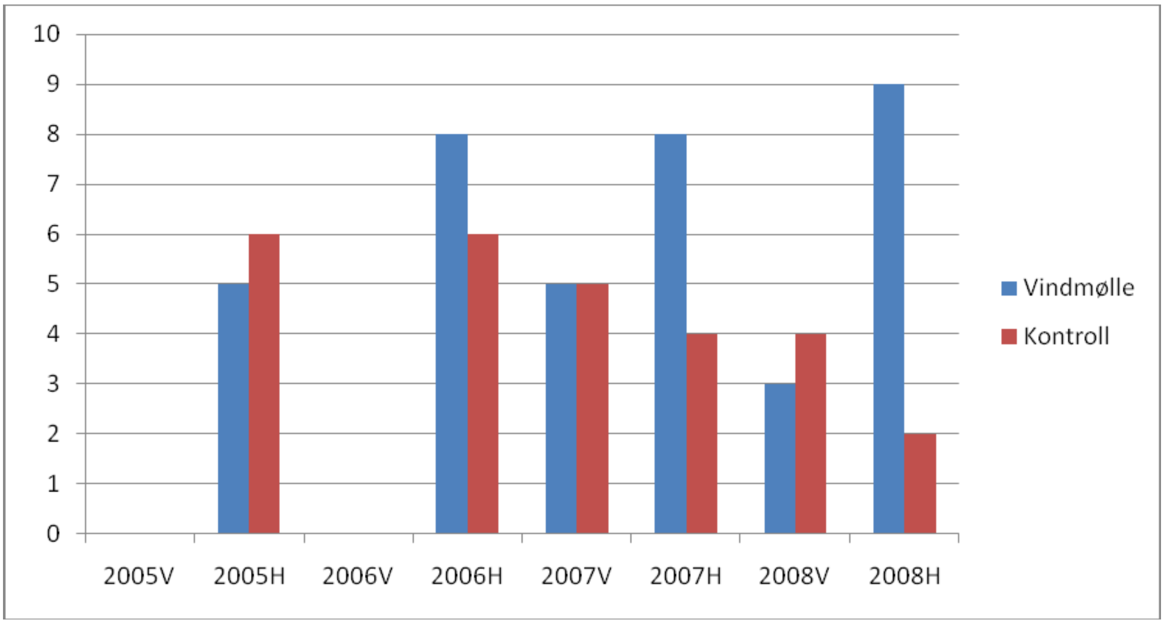

Figure 4. *Population density of willow ptarmigan (birds/km^2) during spring (V) and autumn (H) in the wind power plant area (blue) and control area (red) during 2005-2008.*

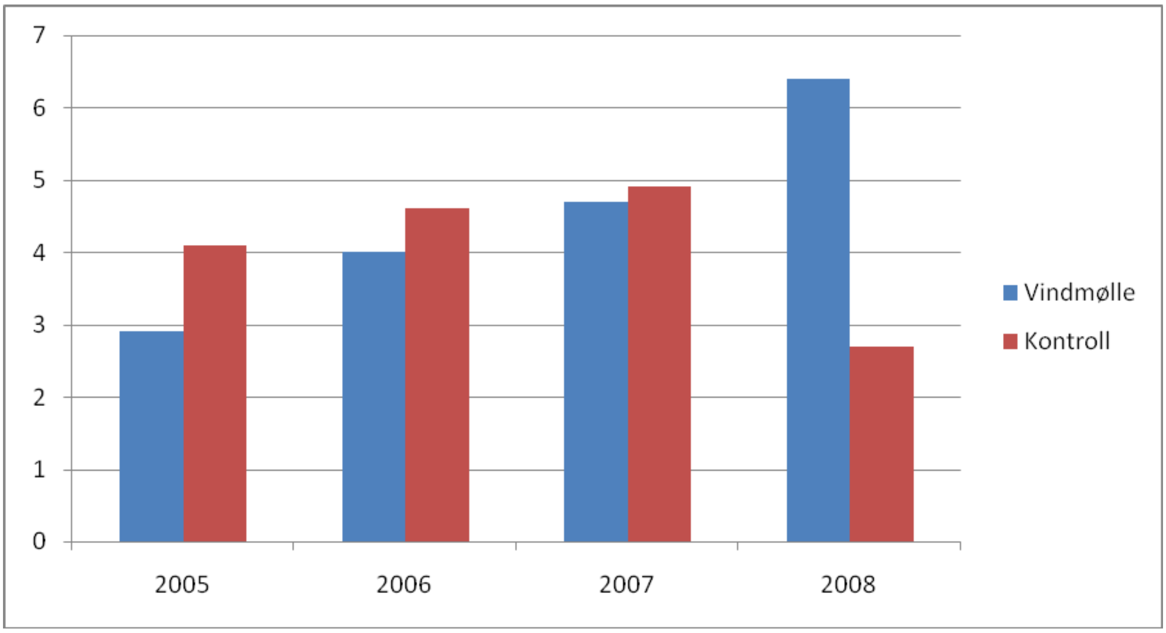

Figure 5. *Chick production expressed as number of chicks per female in August in the wind power plant area (blue) and control area (red) during 2005-2008.*

Figure 6. *Population density of willow ptarmigan (birds/km^2) in August in the wind power plant area (blue) and control area (red) during in 2007-2008 on Hitra.*

Figure 7. *Hans Chr. Pedersen briefing on the willow ptarmigan subproject at the Smøla Meeting in 2008. Photo: Kjetil Bevanger.*

3.3 Eagle owl

Subproject responsibility: Jan Ove Gjershaug and Karl-Otto Jacobsen

The Norwegian eagle owl *Bubo bubo* population has decreased significantly during the 1900s. The present number of breeding pairs is estimated to 408-658 (Jacobsen *et al.* 2008), and the species is categorized as endangered on the Norwegian Red List (Gjershaug *et al.* 2006). One of the most important factors for the decline is electrocution, as the eagle owl uses power poles as hunting posts. Eagle owls are also killed by wind turbines (in Germany, Spain and Sweden 7, 4 and 1 specimen, respectively). From USA it is documented that also the American eagle owl *Bubo virginianus* has been killed by wind turbines. However, so far the knowledge on eagle owls in relation to wind power is fragmentary and scattered. In addition to the risk of being killed by the wind turbines, physical alterations, habitat destructions and human disturbance will probably be the most important negative impacts of a wind power development (Jacobsen & Røv 2007). New power lines in connection to wind power development also involve a risk for electrocution and collision without adequate mitigation measures being implemented.

In 2008 a preliminary study of the effects of power lines on the eagle owl was initiated at Sleneset on Lurøy in Nordland County, a study financed by the Directorate for Nature Management (DN). Applications for funding of eagle owl telemetry studies have also been sent to EBL and Nord-Norsk Vindkraft AS. The latter company has sent an application to NVE for wind power construction at Sleneset. So far these institutions have not been able to allocate money for this. To learn more about habitat use, dispersal and survival, telemetry studies are necessary. Another constraint to eagle owl telemetry studies is connected to DN and The Norwegian Animal Research Authority (NARA), as these institutions want to evaluate an ongoing telemetry project before giving new permissions.

Thus, this year the field work has concentrated on documenting eagle owl mortality in relation to power lines, and nesting locations in the study area. Breeding success was recorded in all known nests and moulting feathers were collected for DNA analysis.

Approximately 9 km power lines were patrolled. Some of the power poles in the study area (figure 8), pose a particularly risk for bird electrocution. The most dangerous are supporting structures for medium-voltage (22 kV) power lines, where the distances between the phase conductors (i.e. the energized non-insulated wires), or the distances between an energized component/phase conductor and an earthed device are rather short. The 22kV power poles have wooden cross-arms, which are frequently used as hunting posts by the eagle owls (figure 9). A particularly high risk construction is power poles with pole mounted transformers and poles where the overhead wires are debranched into underground cables. Several eagle owl carcasses have been recorded beneath these constructions over the last twenty years (Espen Rolv Dahl pers. comm.). These historical data will be analyzed at a later stage.

Dangerous power line sections (pole numbers in bold where dead birds were recorded):

- 092–115: 23 poles including two with transformers (092, 114) and two debranched into sea cables (092, 115).
- 137–145: 9 poles including one with transformer and debranched into earth cable (137) and one debranched into sea cable (145).
- 146–170: 18 poles including two with transformers (**149**, **165**) and two debranched into sea cables (157, 170).
- 171-189: 19 poles one with earth cable to a ground located transforming house (**176**) and one debranched into sea cable (171).
- 213 is debranched into sea cable, and 214 has connection to earth cable to a ground located transforming house.

Electrocuted birds
Dead eagle owls were recorded beneath pole 149, 176 and 184, and dead white-tailed sea eagles were recorded in connection to 165 (two birds) and 177 (one bird). Two dead crows were found beneath pole 176.

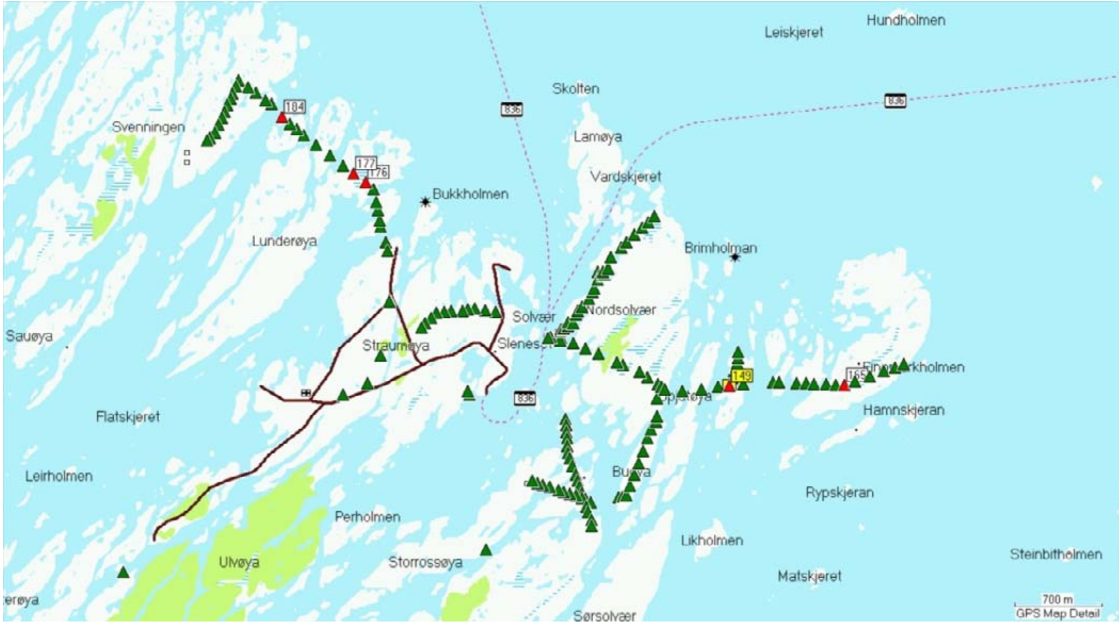

Figure 8. *Power lines and poles inspected on Solværøyene on Lurøy in July 2008.*

Figure 9. *Eagle owl perching on the crossarm of a 22kV pole (no 148). Pole no 149 with pole mounted transformer in the background where bones of one dead eagle owl was found in July 2008. Two dead eagle owls were recorded beneath the same pole in spring 2005. Photo: Jan Ove Gjershaug.*

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3.4 Waders and smaller passerines

Subproject responsibility: Duncan Halley

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

Ideally, distribution and populations of species of interest should be studied by monitoring both before and after construction. This has not been possible on Smøla. A two-pronged strategy has therefore 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 Nordland. A wind power installation is planned for this site, with construction beginning at earliest in 2009 (Asgeir Andreassen, project manager, *pers comm*.; see http://www.andmyranvindpark.no/). Comparative post-construction studies will then be carried out at this site. An EIA of the site has been carried out by NINA (Bjerke *et al*. 2004). The installation will consist of 32-64 turbines of 2.5-5.0 MW capacity in a geometric array of 10-12 rows of 2-6 turbines, generating up to 160 MW, with ancillary roads, buildings, and a new overhead power line. The total site area is 11.05 km^2.

Post-construction monitoring on Smøla: Thirty 1 km transects were defined in the wind power plant area: 10 in the middle of the power plant area, 10 on the western perimeter, and 10 on the eastern perimeter. In addition, two control areas were set up, 10 transects on Toppmyra in similar terrain to the east of the power plant area, and 10 to the west in broken moorland resembling the western power plant. Transect lines in each block were 200 m apart, and birds recorded for 100 m to either side (using rangefinders to gauge distance). Each of the 5 blocks therefore consisted of 2 km^2 of terrain. These were surveyed with the intention of collecting quantitative and qualitative data on waders and smaller passerines. Each transect was surveyed three times in the period 30.5.2007 – 1.7.2007, following a modification of the procedures in Brown & Shepherd (1993).

The resulting data has been digitised. The distance of each location to the nearest wind turbine location has been calculated using GIS tools and programming developed for the purpose by Sigbjørn Stokke at NINA. A comparative set of random locations has been generated for each species and transect. Bootstrapping procedures were used to increase effective sample size for statistical purposes. The data is now ready for detailed analysis, which will be performed in the coming months.

Below we present raw data on bird positions in relation to wind turbine distance, for the four commonest species in the wind power plant area. It should be stressed that this data must be treated with caution until analysed fully, in particular for confounding effects such as variation in habitat correlated with distance to turbines; and corrected for relative availability of terrain at various distances from turbines (particularly relevant to the central wind power plant area).

Figure 10 shows the distribution of the four commonest species in the wind power plant area in relation to distance to the nearest wind turbine, at the eastern and western perimeters of the power plant, the area surveyed being a 2 km^2 area from 0 to 1000 m east or west of the outermost turbine array, respectively.

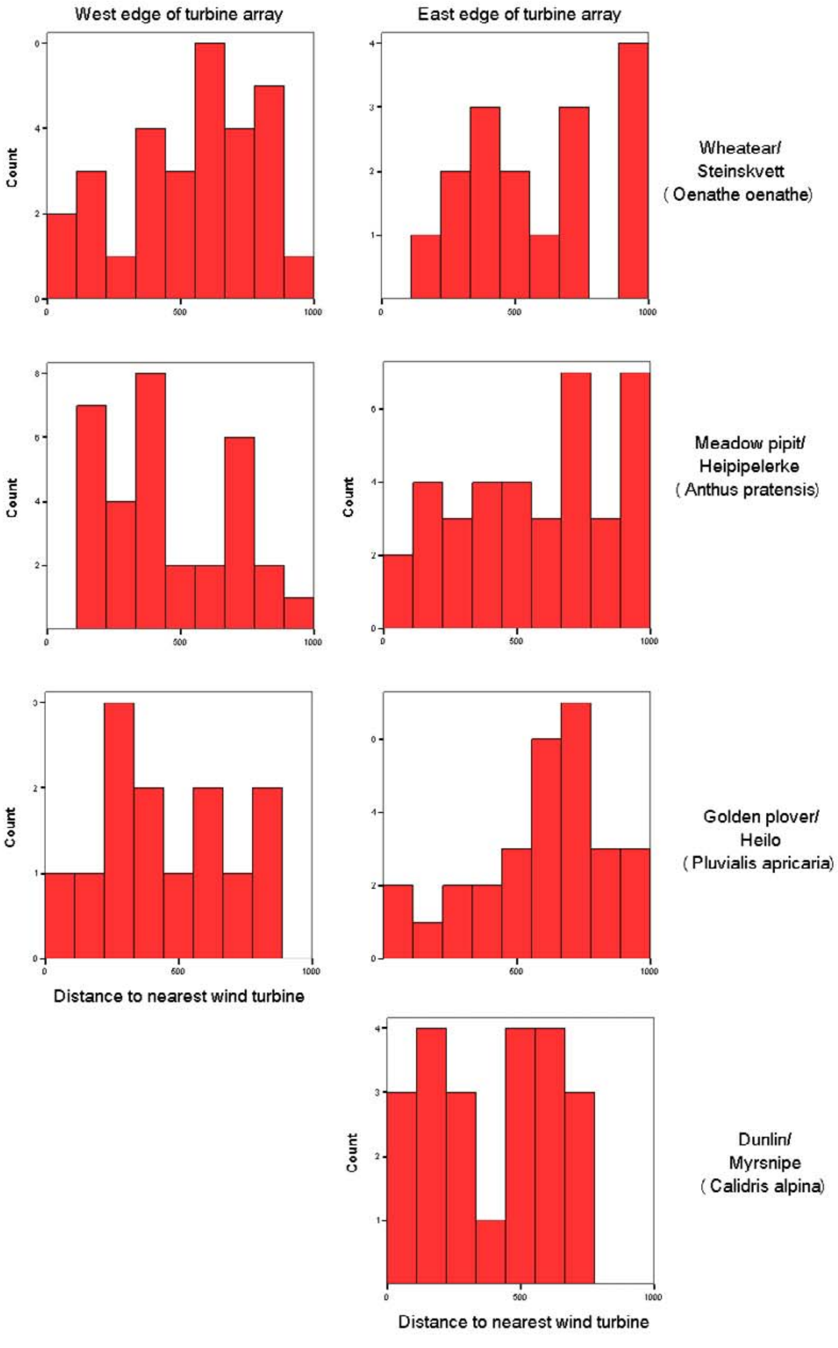

Figure 10. *Positions of four bird species in relation to distance to the nearest wind turbine, in a 1000 m (east-west) x 2000 m (north-south) area extending outward from the outermost turbine arrays on the east side and west side of the wind power plant area. No dunlins were recorded in the western study area.*

There appear to be indications that wheatears were found more often with increasing distance to turbines on both sides of the wind power plant. Meadow pipits show a less clear tendency, although occurrence very close to the turbines seems less common than would be expected.

Wader sample sizes are smaller; there may be a tendency for golden plovers to be more common away from turbines at the east edge of the power plant, but there seems little sign of a distance effect either for golden plovers on the west margin of the power plant, or dunlin at the east margin.

Data for the four commonest species in the central section of the power plant are presented in figure 11. The survey area was a 1000 m x 2000 m section in the central part, bounded by grid references 32VMR 455322, 465322, 455302, and 465302. It contains sections of two turbine arrays running roughly SSE to NNW, turbines 4-6 and 45-51 lying within the survey area. No part of the survey area was more than ca. 450 m from a wind turbine (including turbines out-with the survey area), and most places considerably closer. Birds would therefore be expected to be found considerably less often in the last quartile of the distance-to-turbine out to 450 m due to the lesser availability of locations at that distance. This factor will be adjusted for in the course of detailed analysis. Nevertheless, for all four species there seem to be indications of a marked tendency to avoid areas close to turbines in the central part of the wind power plant, albeit that the sample size for golden plovers and dunlins was low. We stress again that this is raw data, and comparison with random data will be necessary to remove the effects of un-evenness in the availability of locations at varying distances to turbines and of habitat effects, but for wheatears and meadow pipits in particular, the pattern is very marked. The potential effects of disturbance caused by service road traffic (which mainly run alongside turbine ar-rays), and of the wind power plant headquarters, which is located within the central survey area and generates relatively heavy vehicle traffic along access tracks, on bird location must also be considered. These data will be analysed in detail in the coming months.

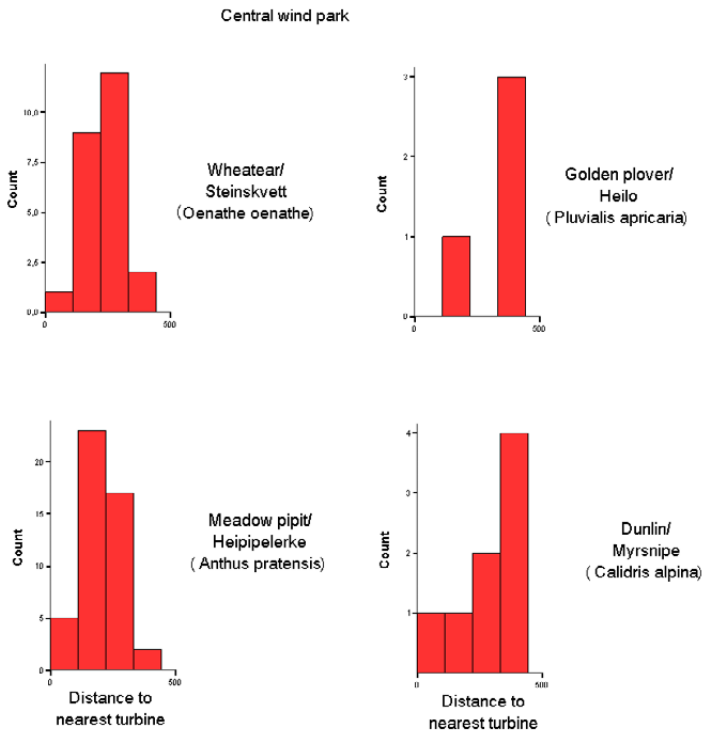

Figure 11. *Positions of four bird species in relation to distance to the nearest wind turbine, in a 1000 m (east-west) x 2000 m (north-south) area in the central part of Smøla wind power plant area; see text for details of location and discussion of data interpretation; in particular, availability of locations at various distances from wind turbines is not even. No part of the area was more than ca. 450 m from a wind turbine*.

Baseline pre-construction monitoring at Andmyran: 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 2.7.2008-17.7.2008 (the breeding season is later on Andøya, which is approximately 650 km north of Smøla).

The proposed Andmyran wind power plant (figure 12) is located in an area with mainly flat mire, and 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.

Data analysis will take place after comparative data is obtained in the post-construction phase.

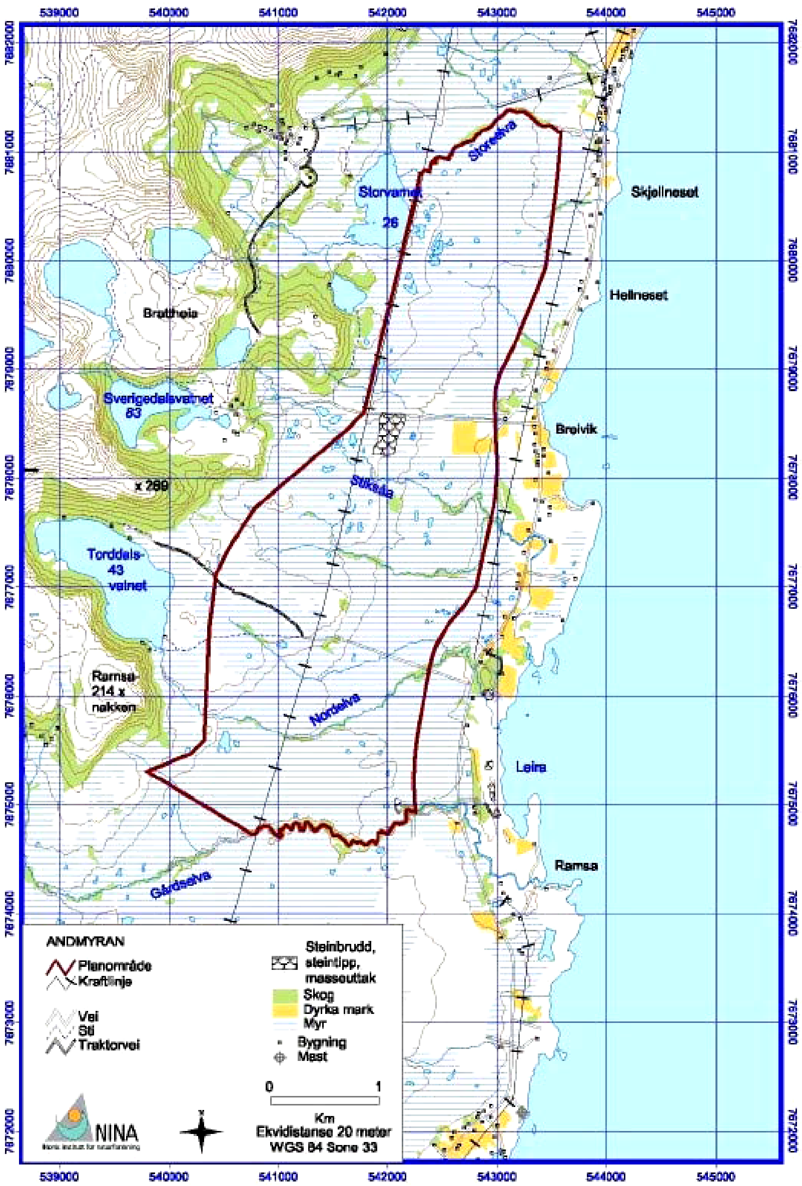

Figure 12. *Proposed perimeter of Andmyran wind power plant (map from Bjerke et al. 2004).*

Figure 13. *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: Duncan J. Halley.*

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3.5 White-tailed sea eagle

3.5.1 Telemetry studies and risk assessments

Subproject responsibility: Torgeir Nygård

Satellite-tagging of juvenile sea eagles on Smøla started in 2003, and since then 43 chicks have been tagged, of which 37 have given results. Three types of satellite tags have been used; Televilt Posrec GPS (3), Microwave Telemetry GPS solar-powered (27), and Microwave Telemetry GPS battery-powered (7). Only the latter two types have been used since 2005.

In 2008, nine nestling sea eagles were tagged, seven with solar-cells and two with batteries. Three of these have quit transmitting, and have not been recovered. No satellite-tagged young eagles have been proven killed by turbines since last year. 21 birds have given GPS-positions in 2008. Due to failed breeding, no juveniles were tagged within the wind power plant area in 2008.

Data are downloaded at regular intervals (about twice a week) to check for their current positions. Repeated signals from same position indicate death or transmitter loss. It is important that such incidents are reacted on quickly, to ensure that such incidents are classified properly. In this way one transmitter was recovered on Hitra using its mortality frequency and it was evident that the bird had freed itself from it. Such verifications are important when coding data for survival analysis.

Following an invitation from NABU (Naturschutzbund Deutschland), results and analyses from the satellite-tagging were presented at an international workshop in Berlin 21-22 September 2008. The results from Smøla are unique in its kind, and they gained high recognition at the workshop. A first attempt at calculating collision risk and avoidance rates was presented.

A regular seasonal pattern of movements emerges when plotting distance from natal site against month (figure 14). Both sexes disperse in the summer, but return in winter/early spring to the area close to the natal site. Spring is the time of year when most mortalities associated with wind turbines occur. The distribution of positions of birds during March-May in their second calendar year is shown in figure 15. Two out of three turbine-killed birds are from this period.

Preliminary analyses of the spatio-temporal distribution of the satellite-tagged birds indicate an overall avoidance rate on a yearly basis of ca. 95%, but as little as 70% in March-May (figure 16). There are, however, many uncertainties regarding these calculations. More sophisticated models, such as the Band Model should be tested out. There is, however, a tendency in the U.S.A. toward using the mortality data themselves to establish risk models (K. Shawn Smallwood, pers. comm.).

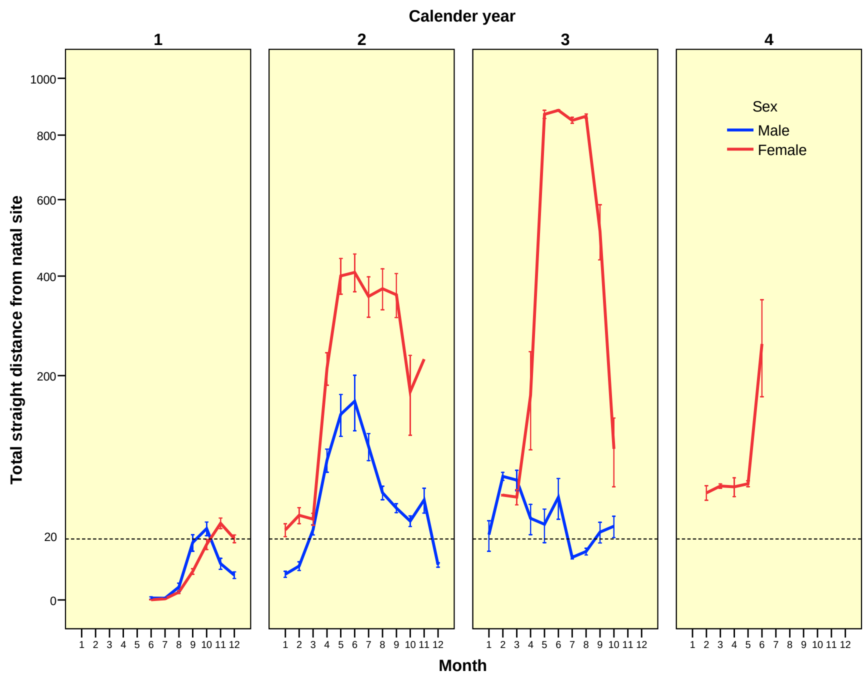

Figure 14. *Mean distance from natal site of juvenile white-tailed sea eagles satellite-tagged on Smøla, plotted against month and calendar year.*

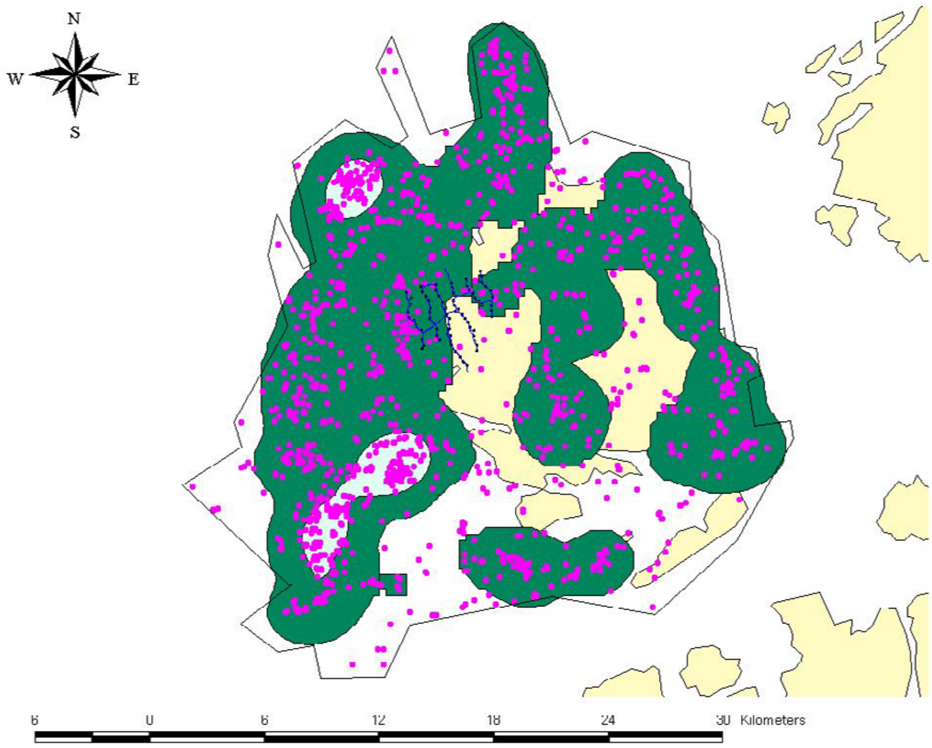

Figure 15. *Positions and kernel areas (95 and 50 % probabilities) of satellite-tagged juvenile white-tailed sea eagles during March-May in their second calendar year*.

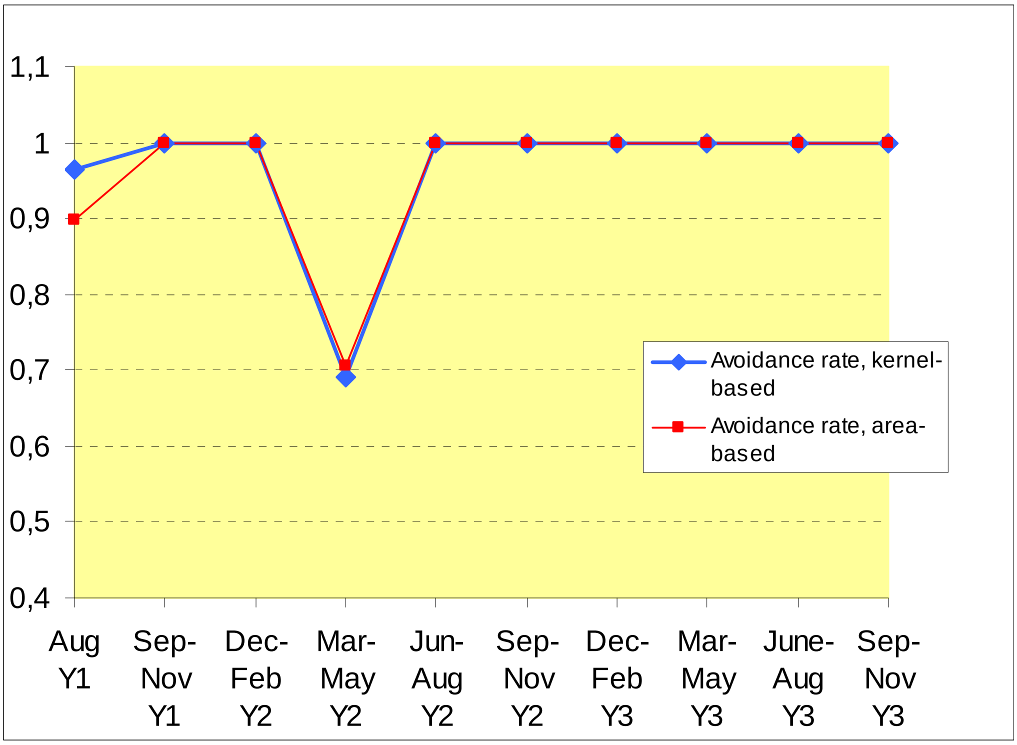

Figure 16. *Theoretical seasonal avoidance rates based on size of area (whole Smøla (red) and kernel areas (blue)).*

Figure 17. *Torgeir Nygård briefing on white-tailed sea eagle movements at the Smøla Meeting 2008. Photo: Kjetil Bevanger.*

3.5.2 Genetic analyses

Subproject responsibility: Arne Follestad and Øystein Flagstad

Objective: Calculate adult mortality among breeding sea eagles in, or close to, the wind-power plant on Smøla compared with pairs breeding further away.

The project will meet the objective by analysis of DNA-profiles from feathers collected from young birds, and moulted feathers from adults collected in the vicinity of the nest. Based on the DNA-analyses, the following issues will be addressed:

- Map the breeding territories of adults killed if they belong to the Smøla breeding population.
- Map adult mortality in the population by determining parentage of chicks in a nest. Time series data will reveal shifts in breeding partners, indicating when one of the parent birds dies. This gives data on adult mortality in the population, which is crucial for modelling population dynamics and the risks connected to a wind-power plant.
- Genetic analyses of feathers can show whether young birds hatched within the wind-power plant area later establish themselves as breeders, and where they will do so.

Moulted feathers from adult eagles and plucked feathers from chicks have been collected yearly in 2006-2008 from all known sea eagle territories on Smøla, both within the wind-power plant and further away from the plant. The project has demonstrated that females are most easily sampled from this approach (more frequent moulting at the nest). However, males also moult readily at the nest, and analysis of a sufficient number of feathers from each nest should give good data on both males and females. As such, our goal is to build a time-series database covering at least 80% of the breeding population on Smøla. In a separate proposal to NFR, we suggested also using a control population that is not influenced by wind-power development, however this part of the application did not receive funding.

Methods for DNA-extraction and PCR-amplification have been thoroughly tested in this project. A panel of 13 microsatellite markers that are highly polymorphic in the population on Smøla were selected after testing: Ha1, Ha5, Ha6, Ha7, Ha9, Ha12, Ha13, Ha14 (Hailer et al. 2005) and AG04, AG05, AG12, AG14, AG15 (Busch et al. 2005). A multiplex PCR set-up has been developed to ensure efficient data production. As the genetic variation is high in the selected markers, only a subset is needed to distinguish reliably between individuals from the moulted feathers at the nest sites. The additional markers will be used for all identified individuals (one sample per individual) to ensure sufficient resolution for reliable relationship analysis (Marshall et al. 1998, Queller & Goodnight 1989). Examination of kinship between nestlings and adult eagles detected at the nest site is necessary to verify that the identified adult eagles indeed are the parents of the chick(s). Kinship analysis is also important to verify shifts in breeding partners.

In 2008 the laboratory analysis of samples collected in 2007 are completed. Moreover, the laboratory protocol for sex determination is developed. The original protocol was designed to handle relatively long DNA fragments, and the templates from some of the moulted feathers were too degraded to be reliably analysed. The ARMS method is now followed (described in Ito et al. 2003), specially developed for birds belonging to the Accipitridae family (like the white-tailed sea eagle). This protocol is designed to handle shorter DNA fragments and is ideal for partly degraded samples such as moulted feathers.

In addition to the laboratory work, feathers from active nests and chicks have been collected also in 2008, as well as from eagles killed in collisions. Sampling of feathers from sea eagle territories in 2006-2008 can be summarized as follows:

Feathers sampled all three years:	15 territories
Feathers sampled in two years:	20 territories
Feathers sampled in one year:	24 territories

Due to little or no funding of the DNA analysis in 2008, no further analysis of this material has been undertaken.

The DNA profiling of moulted feathers and chicks at the nests has made it possible to produce a database of individuals from the breeding territories on Smøla. So far the entire couple (male + female) in19 territories were sampled, which is approximately 35% of the territories sampled in 2006 and 2007. The rest of the territories were provisionally represented by one bird only, most often the female. Limited resources have hampered an even higher representation of whole pairs, but given that sufficient funding can be raised, it seems realistic to fulfil the goal and produce a database comprising at least 80% of the breeding population.

After only two years of analysis, it is far too early to say anything about the adult mortality in the population. There have been a few examples of one new bird at the nest, but another year of data will be needed to exclude the possibility that this could be a visiting, unrelated bird. It is also too early to draw any conclusions on the origin of the dead birds. Only two of the birds analysed so far can be directly connected to the database of adults and young birds. However, denser sampling of moulted feathers is needed in order to quantify the true proportion of the casualties belonging to the breeding population at Smøla

As indicated above, a time series database of individual breeding birds is crucial for mapping adult mortality in the population, which in turn is an essential element to obtain a detailed understanding of the effects of the wind power plant. These results may, if or when they are produced, be important for other subprojects on Smøla, such as:

- Monitoring dead birds. Evaluation of the effect to the local population will depend on the origin of the birds found dead. Are they local birds in or close to the wind power plant or do they originate outside Smøla?
- Monitoring breeding numbers, their location and reproductive status. It will be important to know if a nest in or close to the wind power plant is abandoned because one of the adults have been killed, or by other reasons/effects of the wind power plant.
- Modelling population dynamics in the sea eagle. Reliable input data on adult mortality will be crucial to be able to interpret the effects of the wind power plant both on a local and a regional scale.

Sampling of feathers from chicks and moulted feathers from adults may be a simple and cost-effective measure to map the patterns of adult mortality in other wind power plants, as focus on cumulative effects may become a central theme for nature managers when evaluating the effects of wind power plants in Norway.

Some results from 2006 and 2007:

- A male from a nest west of the wind farm (with reproduction in 2006), was found on a neighboring nest in 2007. This might indicate that what has earlier been judged as two separate territories now must be considered as one.
- Feathers found at a territory between two others, not belonging to the birds there, indicate that there is a third territory in this area, between the two known from earlier studies.
- A new female was found on a nest west of the wind farm in 2007. The old female, represented with four feathers in 2006, was not found in 2007. This suggests that the female from 2006 is either dead or has moved to another territory.
- The female from a nest in the SW archipelago in 2006, was observed both on this nest and on a nest some kilometers further north the same year. The same bird was observed and fledged two juveniles on the northern nest in 2007, but was not observed on the southern nest. This may suggest that the female has changed territory, but the reasons for this shift are unclear.
- Samples from the six adult eagles found dead in 2008 was compared to feather samples from 2006 and 2007. This gave two matches:
- Male with a brood patch found dead 3rd April at turbine 52, from a territory 1-1,5 km SW of the wind farm.
- Male found dead 16th April at turbine 64, from the Brattvær area, in a territory about 8 km from turbine 64.

This demonstrates that at least two of the adults found dead in 2008 belong to the breeding population at Smøla. These results are highly important as they show that the impact area of the wind farm may be far greater than the wind farm area itself and the surrounding area within one or two kilometers. The number of matches might be increased by increasing the number of feather samples analyzed from 2007 to get DNA-profiles from both parents, and by analyzing the feather samples from 2008.

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3.5.3 Breeding success and breeding on Smøla

Subproject responsibility: Espen Lie Dahl and Torgeir Nygård

The breeding population of white-tailed sea eagle on Smøla has been closely monitored during the last decade. Each year every known eagle territory has been visited at least once a year during the late breeding season. The main focus during this survey is to check if they are occupied by adult birds, and to see whether the nest(s) are lined with fresh materials, and finally to record reproductive output. The aim of this population monitoring is to record important population parameters and to investigate whether these are affected by the wind power plant on Smøla.

Adult sea eagle pairs do not breed every year, and in the intermittent years their behaviour can be very inconspicuous. Due to this it is very difficult to confirm territory occupancy by all adult pairs in the population every single year. This means that the real population size is very likely to be higher than the number of territories with recorded activity any given year based upon just one visit.

Territorial activity, as revealed by either moulted adult feathers or fresh nest material, was confirmed in 58 different territories on the main island of Smøla and in the surrounding archipelago in 2008. A total of 21 chicks from 14 different clutches were recorded, giving a reproductive output of 0.36 chicks/confirmed occupied territory. In the wind power plant area, two pairs laid eggs closer than 500 m from the turbines (W of T28, NE of T33). Both pairs failed, resulting in no chicks produced inside the wind power plant area in 2008. Neither of the two nests contained eggshells at the time when they were surveyed, strongly indicating that both pairs have discontinued their breeding attempts during the incubation period. The reason is not known, but none of these pairs were among the birds found killed beneath the turbines (based on observations). In the buffer zone surrounding the wind power plant area two pairs bred successfully, producing four chicks.

A master thesis (Dahl 2008), finished this September, investigated effects of the Smøla wind power plant on breeding success in sea eagles by using a BACI approach (before – after – control – impact). Data from 52 eagle territories from the period 1996-2007 were analysed using a general linear mixed model. This study concluded that there was a significant effect from the interaction between time period and distance to turbines. Territories within, or close to, the wind power plant area in the time period after development experienced significantly lower breeding success than the same territories before development. This effect was strongest close to the turbines and became weaker with increasing distance to the turbines, although being significant up to 3 km. There were also significant negative effects from time period (before/after) and distance (inside/outside) alone, although these were less important than the effect from the interaction between the two.

For further analyses of important parameters in the Smøla sea eagle population a database is now being constructed. This database contains geo-referenced data on activity from all known sea eagle territories on Smøla, covering an extensive time period.

3.5.4 White-tailed sea eagle behaviour inside and outside the wind power plant

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

Objectives: Observation of white-tailed sea eagle 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 observation sites were selected in the wind power plant area and in an area with similar topography outside the wind power plant as a control area, with 6 vantage points within the wind power plant area and 6 within the control area. Each vantage point had an observation-radius of 1 km. The data was collected from mid-March to end of May 2008 and includes 144 observation hours. The observations were distributed during the daytime into 4 observation periods, with 2 hours in each observation period. Altogether 244 observations were recorded, with a total of 1037 events. Each time the observed individual changed behaviour or flight height, this was recorded as a new event. In this way each individual could have from one to several recorded events. For each observation, data have been collected about behaviour, age, flight height and duration of the activity.

A rangefinder was used to measure distance between the observer and bird, and GPS coordinates for each observation has been plotted on a map using GIS. The angle of the observation has also been collected (with zero degrees in north, 180 in south etc.). Plotting these data in GIS can be a useful tool in order to visualize the flight paths for the observed individuals. Distance to nearest turbine and to nearest active nest has also been collected with the use of GPS coordinates. Weather data for the study period have been acquired from Statkraft, and these variables may be used as possible explanatory variables for the eagle behaviour.

Preliminary results indicate that, inside the wind farm area, spiralling/playing are the activity performed closest to the wind turbine (mean=153m, min=15 m, max=371 m), while chasing/fighting occur furthest away (mean=241 m, min=65 m, max=459 m). Both inside the wind power plant area and in the control area the flight activities in particular seems to occur above rotor height, but the eagles also seem to use much time in rotor height and very high (figure 18). It seems to be a similar distribution between the activity categories inside the wind power plant area (moving flight 45%, chasing/fighting 6%, spiralling/playing 27%, soaring 21) and in the control area (moving flight 52%, chasing/fighting 9%, spiralling/playing 21%, soaring 18%). It is a similar age distribution between number of observed individuals inside the wind power plant area (57% adults and 43% subadults) and the control area (64% adults and 36% subadults).

There is more activities in April (total 72%) than in March (total 16%) and May (total 12%), and preliminary results also indicate that the largest differences in flight activities between the wind power plant area (March 11%, April 76%, May 12%), and control area (March 19%, April 68%, May 12%) occur in April (see also figure 19 and 20). Looking at the distribution of the activities during daytime, the activities seems to peak at the end of the day inside the wind power plant area (8-10am: 5%, 11-13am: 28%, 14-16am: 35%, 17-19am: 32%) while in the control area it seems to be peak activities during middle of the day (8-10am: 20%, 11-13am: 36%, 14-16am: 24%, 17-19am: 19%).

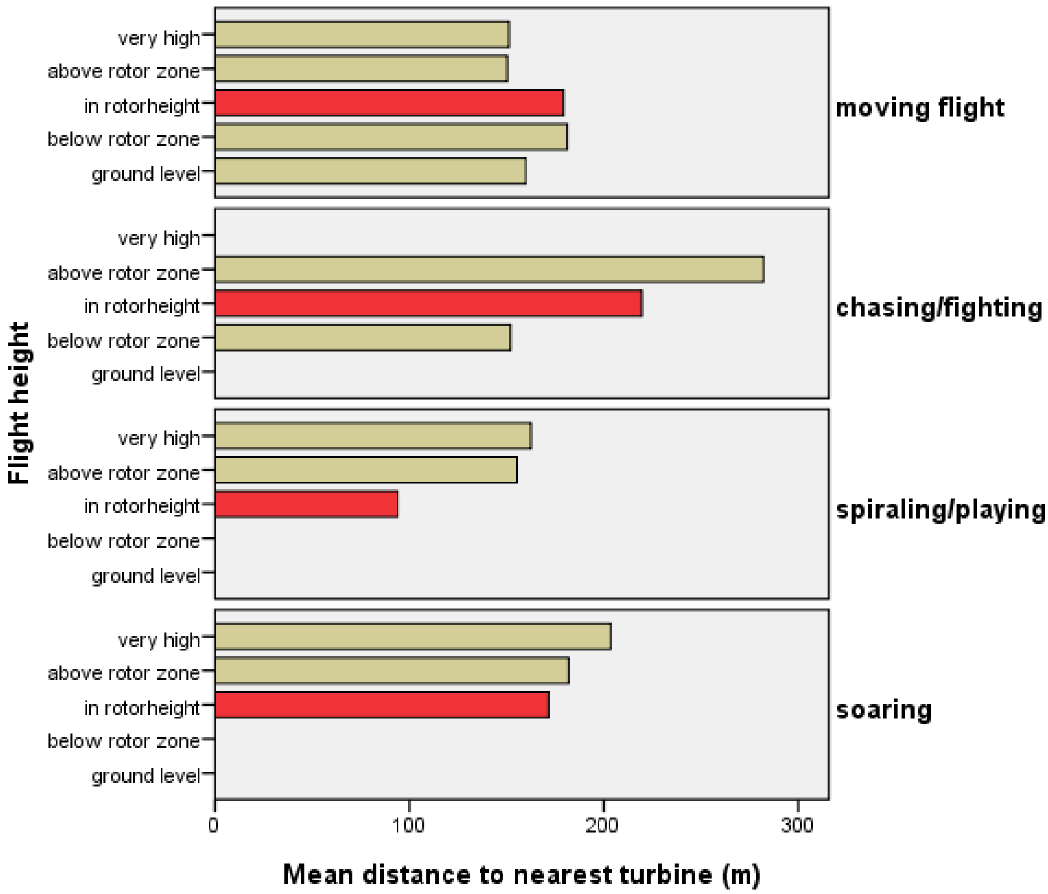

Figure 18. *White-tailed sea eagle activities inside the wind power plant area in relation to flight height and distance to nearest turbine. A majority of the activities occur above the rotor zone, but it also seems to be significant activities in rotor height and very high. Spiralling/playing are the activity being performed closest to the turbines, while chasing/fighting occur furthest away*.

Figure 19. *The white-tailed sea eagle activities are peaking in April. Moving flight, spiralling/playing and soaring are observed in all three months, while chasing/fighting only is observed in April.*

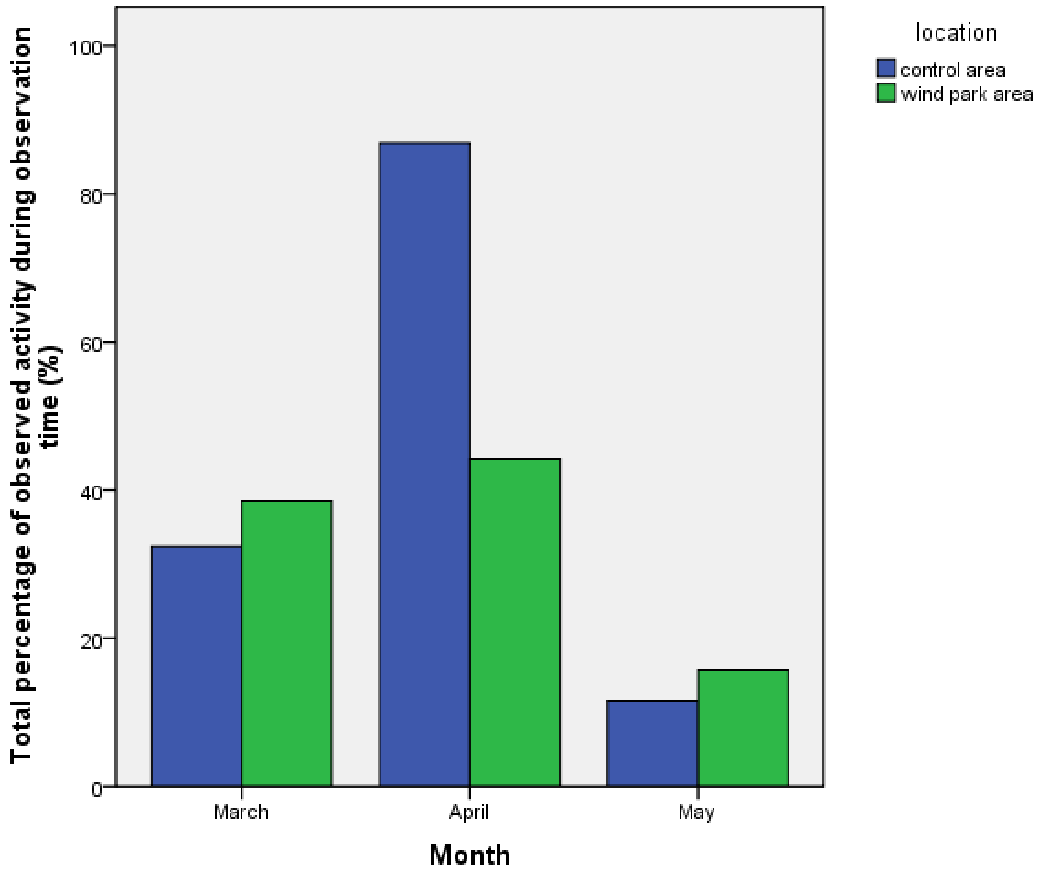

Figure 20. *The white-tailed sea eagle is significantly more active in April compared to March and May. The differences in observed activity within the wind power plant area and control area is also highest in April.*

Further analysis will reveal whether variation in flight activity can be explained by weather variables, time of day, age etc. In addition, it can be relevant to define some risk-zones and compare the activity to these.

Figure 21. *Pernille Lund Hoel collecting data on sea eagle behaviour inside and outside the wind power plant area. Here assisted by Espen Lie Dahl. Photo: Kjetil Bevanger*.

3.6 Bird radar studies

Subproject responsibility: Roel May and Yngve Steinheim

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

3.6.1 Radar installation

Yngve Steinheim from SINTEF, together with Kjetil Bevanger from NINA, visited DeTect headquarters in Florida in late January and attended a "Factory Acceptance Test (FAT)") for the radar. This was in compliance with the contract stating that "*The FAT will include operational demonstration of the functional components of the system and will document that the unit is complete, functional and calibrated for delivery*".

The radar was shipped from Florida in early February and arrived at NINA Headquarters in Trondheim in late evening March 7. Andreas Smith from DeTect had arrived in advance of delivery to tailor the radar computer equipment for Norwegian conditions.

A permit to operate the system within the Statkraft wind power plant area at Smøla has been obtained from the Norwegian Post and Telecommunications Authority.

Figure 22. *Factory Acceptance Test at the Detect Factory in Panama City, Florida. Photo: Kjetil Bevanger.*

Figure 23. *The radar arrived safe at NINA on March 7 - solidly wrapped. Photo: Kjetil Bevanger.*

The radar was pulled with a SUV to Smøla on March 8th 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.

Figure 24. *On March 8th the MERLIN radar was pulled on her trailer the approximately 200 km from Trondheim to Smøla - on partly slippery roads. Photo: Kjetil Bevanger.*

After much trial and error the most suitable location to place the radar was in the centre of the wind power plant (see figure 25). 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 or southwest.

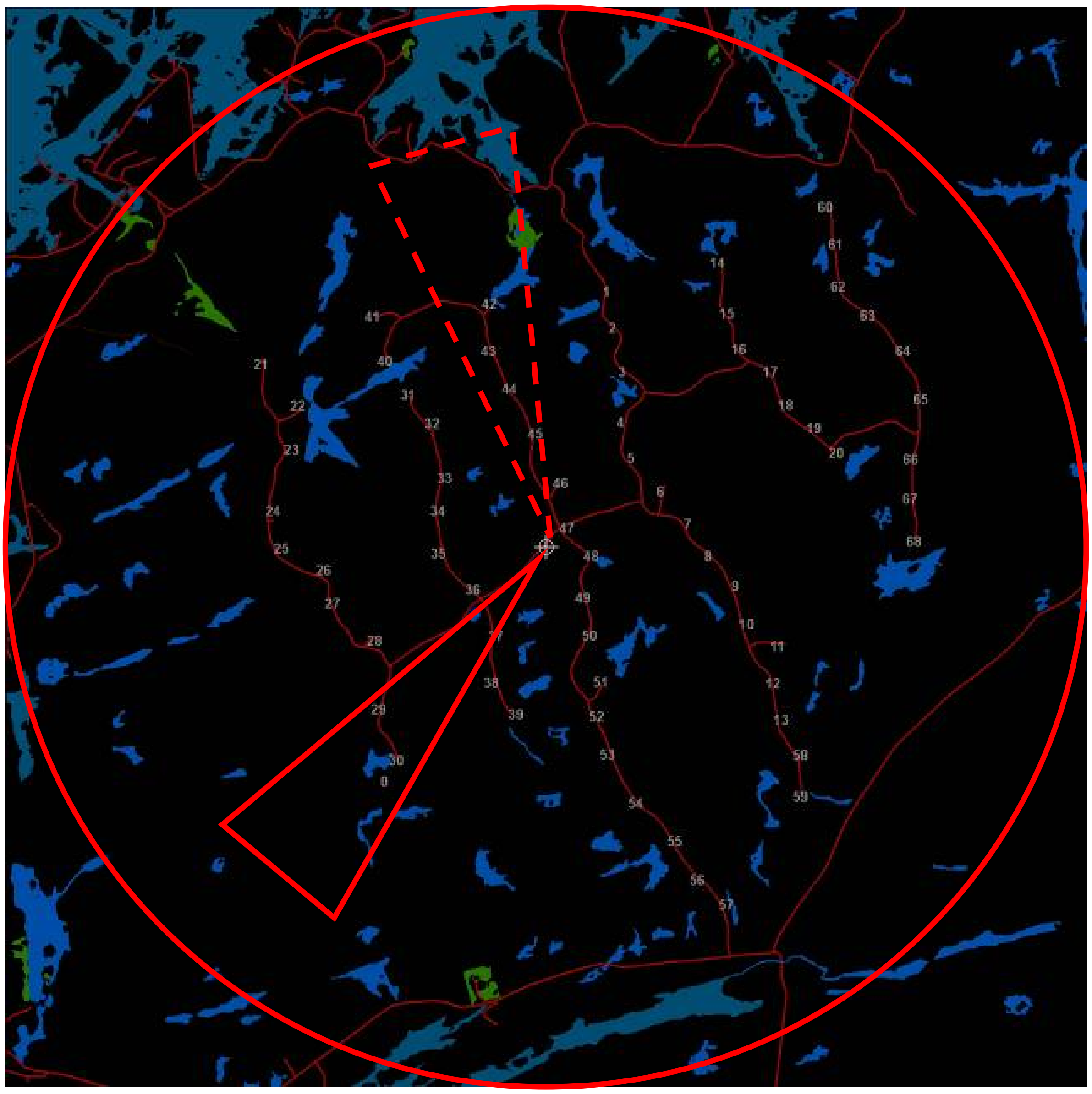

Figure 25. *Placement of the MERLIN Avian Radar System at the Smøla wind power plant. The circular area shows the coverage with the horizontal radar; the two strips indicate two different placements and coverage for the vertical radar*.

Since April 3rd 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 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 approx. 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. Prior to this, the radar was powered by the generator. During spring we experienced several practical problems with the radar due to temporary generator failures, a radar hardware fault and software related issues. These have now been solved.

3.6.2 Radar data collection management

From the beginning of 2008, Roel May from NINA started a postdoc position which will focus on two main aspects related to white-tailed sea eagles on Smøla. The first part aims to investigate the spatial requirements (i.e. habitat selection and movement patterns) of white-tailed sea eagles at the on-shore wind power plant on Smøla. The second part aims at constructing statistical collision models for estimating the risk of collisions between white-tailed sea eagle and wind turbines, given different wind power plant scenarios. Also the postdoc-study aims to incorporate new methodologies for the assessment of avian collision risks (i.e. on-site mobile radar technology, trained dog searches, video-based detection systems). The postdoc has the specific responsibility for the avian radar.

Figure 26. *Roel May briefing on his main scientific focus as the project postdoc at the Smøla Meeting 2008. Photo: Kjetil Bevanger.*

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

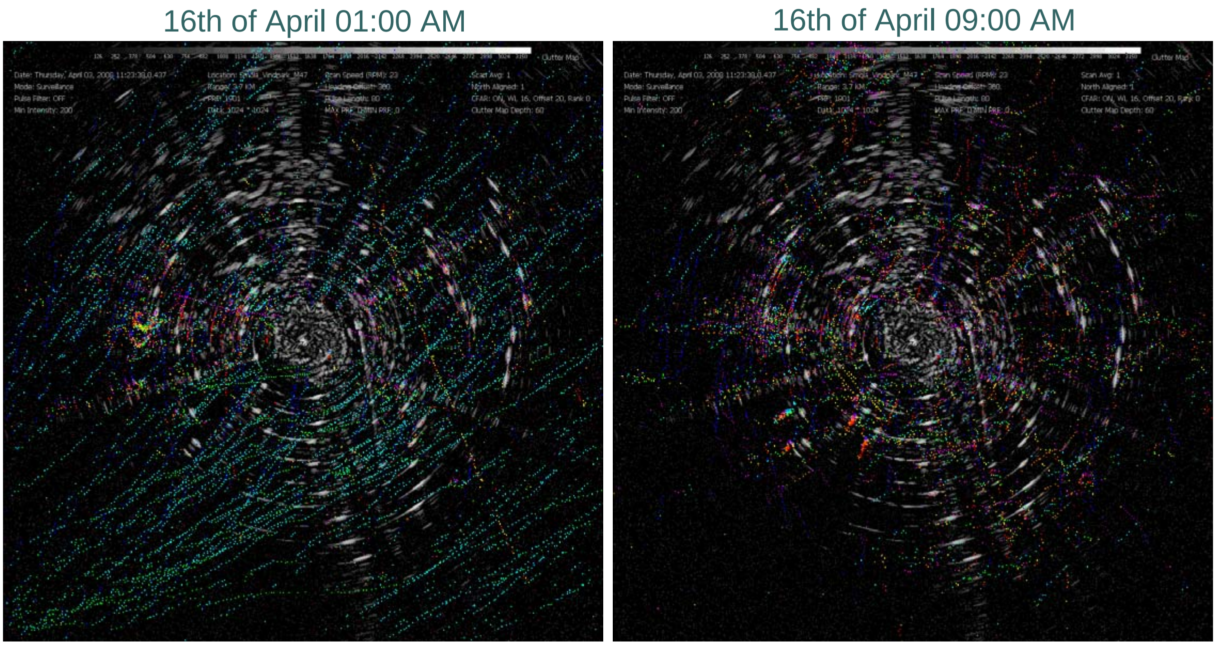

Figure 27. *Example of bird activity on the 16th of April; migration during the night and local activity during the day*.

A central component within the radar studies is the verification whether sea eagles that have been found killed by a wind turbine have actually been tracked by the radar. A first check on the six dead eagles found in spring and summer 2008, revealed that in most cases one or two tracks were recorded to have ended within a 50 m radius of the wind turbine (see also paragraph 3.9.2). These tracks were mostly recorded during late evening or early morning.

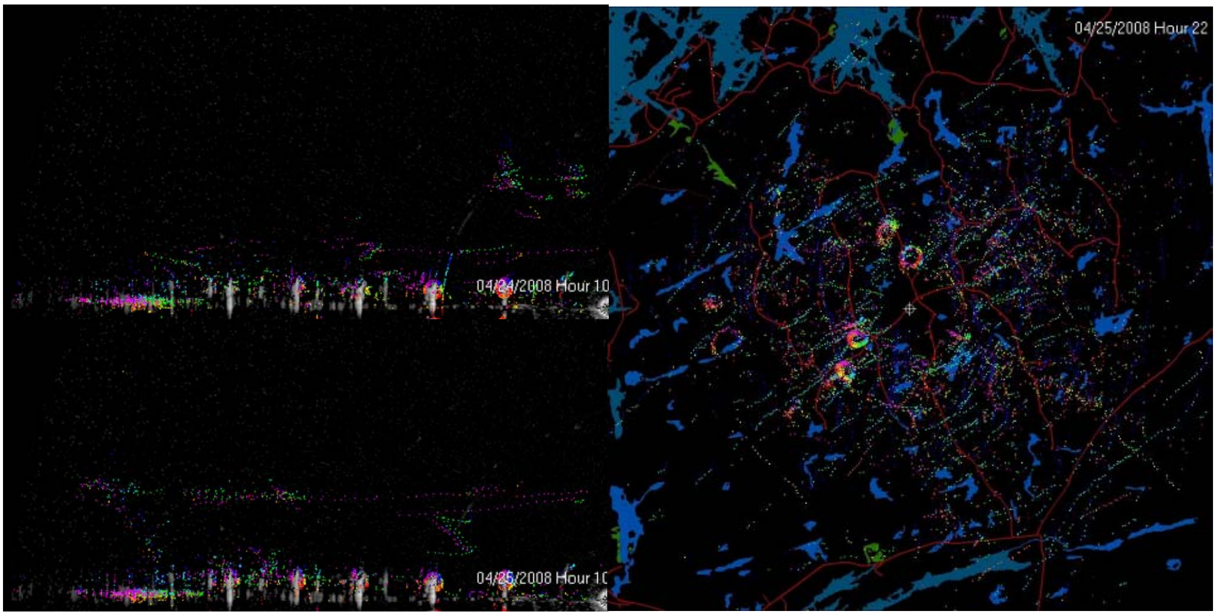

Figure 28. *Example of bird activity: To the left sea eagle circling; to the right so-called "bird circles" of an unknown bird species.*

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 sea eagle behaviour, such as thermal circling (cf. figure 28 – left-hand panel), can easily be distinguished. Also other behavioural phenomena have been recorded this spring; so-called bird circles (cf. figure 28 – right-hand panel). As yet we do not know which species is responsible for these circles, which were performed at one specific altitude below or at rotor swept height, they were created especially at night (21:00-03:00) towards the end of April.

Within the next stages of the project, the methodological aspects of using radar technology will be assessed. This includes ground-truthing radar data, executing detection and calibration tests (see paragraph 3.6.3 and 3.9.4), and developing the information-technological infrastructure for data flow and storage of the many terabytes of data (see paragraph 3.8). When these methodological challenges have been met, filtering of and analyzing the data can commence.

Investigation of the spatial requirements (i.e. habitat selection, flying patterns) of white-tailed sea eagle 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 and radar flight tracks. The spatial responses of white-tailed sea eagles 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.

3.6.3 Radar performance checkout and optimisation

Since week 11 in 2008 the radar has been operating and collected bird flight data from the wind power plant area.

The specific radar location within the wind power plant represents some extraordinary challenges for a radar system. 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 (see also paragraph 3.9.4).

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. To investigate MERLIN performance at its current location within the wind power plant on Smøla, field trials with dedicated controlled targets have been performed. This effort serves 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 is dependent on two components: one random error that is due to statistical variation in receiver noise and influenced by radar parameters like beam widths and receiver noise factor, and one systematic error due to misalignment of the radar to the surrounding terrain, usually both in azimuth 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 3.9.4). This clutter will reduce the detection capability of birds in the affected areas; it is however important to find out to which extent.

The test targets to be used should correspond to the actual targets to be tracked as closely as possible in terms of radar cross section and flight behaviour. For our avian surveillance radar with an instrumented range of 2 nautical miles, our first attempts have been with a model aircraft with a towed sphere. In addition, target accuracy is tested using a car with a handheld GPS on the dashboard.

Figure 29. *Model aircraft and towed sphere. Photo: Yngve Steinheim.*

The aircraft is equipped with a GPS receiver which enables it to record its position continuously for later comparison with the recorded radar data. The radar cross section of a sphere with 15 cm diameter is approximately the same as a sea eagle. However it has proven difficult to resolve the sphere from the aircraft even with towing strings with lengths up to 30 m. So for future tests only the model aircraft will be used as test target, and its radar cross section will have to be measured in the lab in advance.

The first radar performance tests in 2008 have given priority to the horizontal surveillance radar since this part of the radar system has 360° coverage and has the most challenging clutter environment. In addition, it has proven to be difficult to keep the aircraft in the exact centre of the beam of the vertical scanning radar when flying radial patterns and some other method may have to be considered to be able to test the vertical radar.

3.7 Detector and sensor systems

Subproject responsibility: Kjetil Bevanger and Lars Johnsen

Objective: Develop equipment and technology to detect birds in the close vicinity of wind turbines and learn more about bird behaviour close to the turbines and possible effects of rotor induced air turbulence. This may create a future basis for developing methods to reducing the risk of birds being killed by wind turbines.

In its final report from the pilot study in 2007, submitted in April, SINTEF recommended two new methods:

- Camera-based detection of birds with possible automatic wind turbine close down
- Increased visibility through the use of UV-light sources mounted on rotor blades

The implementation phase started in autumn 2007, and a contract (NOK 950 210 (excl. VAT)) between SINTEF IKT and NINA was signed October 10 2007 (”*Fugler og vindmøller, Fase II, implementering-overvåking/deteksjon med kamera*”).

The contract specifies that SINTEF should develop a system for:

- Automatic and selective registration of video sequences including moving objects which may be birds. The system is to function in daylight with good visibility.
- Integrate a Forward Looking Infra-Red (FLIR) camera in the system and deliver a system employing FLIR cameras based on the results of a pilot project carried out within the NFR project.
- Build up the system so that it is ready for further development to register bird coordinates (horizontally and vertically in the picture for one camera, and 3-dimensional for stereo vision).

Figure 30. *Camera system installed in connection to wind turbine 43. Photo: Kjetil Bevanger.*

SINTEF developed the system during the spring 2008, and on the project yearly meeting on Smøla in March a status report was presented by Lars Johnsen, SINTEF: "*Detection and sensor systems – a status report*".

In April-June 2008 a total of 7 video cameras were installed in the vicinity of turbine no. 43. The system includes 6 normal daylight cameras, with three cameras looking up along the turbine tower, and three forward looking cameras - away from the tower. This allows a detailed monitoring of the white-tailed sea eagle behaviour close to the turbine, and at the same time allows 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 are oriented in a manner that make later stereo picture check possible and thus a full 3D object positioning. The FLIR camera gives supplementary information.

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

3.7.1 Implementation of a Phase III of the camera project

During summer and autumn 2008 SINTEF and NINA have met several times and discussed a possible extension of this subproject. As the money given to support this subproject by Statkraft is now exhausted (NOK 1 mill.), an extension will depend on extra funding.

From a technical point of view the developed camera system is functioning very well, although the number of false signals triggering the camera to operate is too high. This makes a cost-effective treatment of the data difficult. The system should be more or less “self-supported” and independent with respect to transformation of the huge data amount into useful and easily accessible information. This requires further methodological development. SINTEF has prepared a project proposal containing several work packages and budget focusing this.

Another problem is connected to the fact that having camera installations only at one turbine reduces the probability for obtaining a sufficient amount of data regarding bird behaviour, e.g. sea eagle, in the immediate vicinity of the turbine. It should thus be considered whether the installation should be duplicated or not. A project proposal for duplication with budget is worked out by SINTEF.

Regarding implementation of a project focusing increased turbine visibility, SINTEF has also prepared a project proposal. The aim of this project is – by means of field experiments – to test weather UV spot lights have any effect on the behaviour of sea eagles approaching the turbines. The role SINTEF will have in this experiment will be to:

- Contribute with technical expertise when scientists from NINA make the experiment design
- Select technical equipment for the experiment
- Implement the experiment and collect data

SINTEF would also be a partner for co-operation regarding the need for better understanding of the turbulence and turbulence pattern created by the turbines and how this affects the birds. For the time being the knowledge is limited regarding turbulence intensity close to the turbines and how local topography contributes to modify the turbulence patterns. From a biological point of view there are several arguments for the needs of increased understanding of the turbulence patterns connected to the wind turbines. Each bird species has specific aerodynamic characteristics, deciding its ability to operate in the air and avoid e.g. artificial obstacles like wind turbines. Actually birds may be grouped and categorized into “poor” and “good” flyers. Combined with their visual abilities this is central parameters regarding the ability to identify - and avoid - by making swift avoidance manoeuvres - unexpected air obstacles.

Another important aspect is the species specific behaviour. 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 to gain height, by which they save energy. The sea eagle 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 has recently been published a paper on how bats are being affected by this. Actually they are dying to the fact that their lungs are ruptured when approaching certain positions relative to the rotor blades; i.e. air pockets with lowered air pressure. SINTEF has made a sketch on how turbulence effects on birds may be modelled to better understand this problem.

3.7.2 Biological rationale for project extension

It is important to understand how birds experience the airspace close to a wind turbine based on the species specific biomechanics and perception abilities. Without detailed knowledge on the behavioural reactions close to the turbines 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. These are the most important arguments connected to a possible prolongation and expansion of this sub-project.

At the Smøla wind-power plant the white-tailed sea eagle and endemic subspecies of willow ptarmigan (smølalirype), have the highest recorded mortality. These two species are highly different with respect to perception abilities as well as biomechanics. The sea eagle 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.

Thus, the tasks ahead should concentrate on increased data collection on how birds, based on their biomechanics and aerodynamic skills, control the turbulence and vortices in the vicinity of the wind turbines, and how they view and understand the movements of the rotor blades and other wind turbine associated structures.

Key issues will be
- whether wind turbine related mortality among birds mainly 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
- and whether the flight path of a bird is affected by the turbine-generated turbulence in a way that may be predicted.

And if so
- whether that 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

In short it is important to increase the species specific knowledge on how a bird flight path is determined by their vision, colour and movement sensibility, and at what distance visual stimuli is perceived. Moreover, it is important to increase the knowledge on decisive parameters (for the birds - vision or biomechanics; for the wind turbine - the rotor blade speed, colour, design and turbulence generating abilities – and how these parameters are modified by local topography and wind conditions). Without this knowledge it will be difficult to develop efficient mitigating measures based on e.g. bird vision and bird biomechanics, which for instance could be a possible change to the rotor blade colour or aerodynamic design to modify the turbulence to be less problematic from a bird perspective. To learn more about bird vision and how this possibly may modify species specific collision risk, Olle Håstad from the University of Uppsala is connected to the project. An aim is that the work made by Håstad may increase our knowledge on what a bird actually is ale to see (field of perception, range, colour etc.).

Studies of spatial effects of wind turbines on bird movement pattern and behaviour are so far connected to sea eagle and ptarmigan, and several individuals have been equipped with radio transmitters. The MERLIN bird radar enables a more or less continuous mapping of bird activity both inside and outside the wind power plant. Unfortunately this will only to a limited extent contribute with detailed knowledge on species specific bird behaviour (e.g. sea eagle behaviour) in the immediate neighbourhood of a wind turbine. Radio telemetry as well as radar is methods mainly developed for studies at landscape and habitat level. Thus, by a further development of the detector and sensor systems at turbine 43, it is possible to record data on bird movements and behaviour close to the turbine. Together with increased knowledge on bird vision and biomechanics, possible changes in bird flight paths may be analysed and connected to perception parameters and local wind conditions (e.g. distance when birds react, how fast they react, avoidance distance and avoidance behaviour). This enables an optimal use of the camera technology and support to the theoretical approaches regarding the importance of bird vision and aerodynamic abilities.

The project proposals made by SINTEF on how to proceed have relatively high costs. Thus, a first step is to clarify whether Statkraft intend to fund with some of them. A memorandum, together with the project proposals mentioned above, was sent over to Statkraft for evaluation on September 17 2008. In this memorandum NINA suggest that Statkraft initiate a meeting with NINA and SINTEF to discuss a possible continuation and extension of the activities.

Figure 31. *A gull passing wind turbine 43 as captured by camera 5 on 2008-05-27 12:50:40.*

3.8 Data flow and storage systems

Subproject responsibility: Roald Vang and 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.

The avian radar system generates huge amounts of raw data when there is much activity around the wind-power plant. 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. We want to be able to reprocess these data later, and therefore we periodically move them to the central storage system at NINA Trondheim. For now we have not got sufficient bandwidth to automatically transfer these files over the network, so the disks are transferred manually. 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 (cf. figure 32).

The 6 cameras positioned around wind turbine 43 (figure 33) 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 (cf. figure 34). 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. 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.

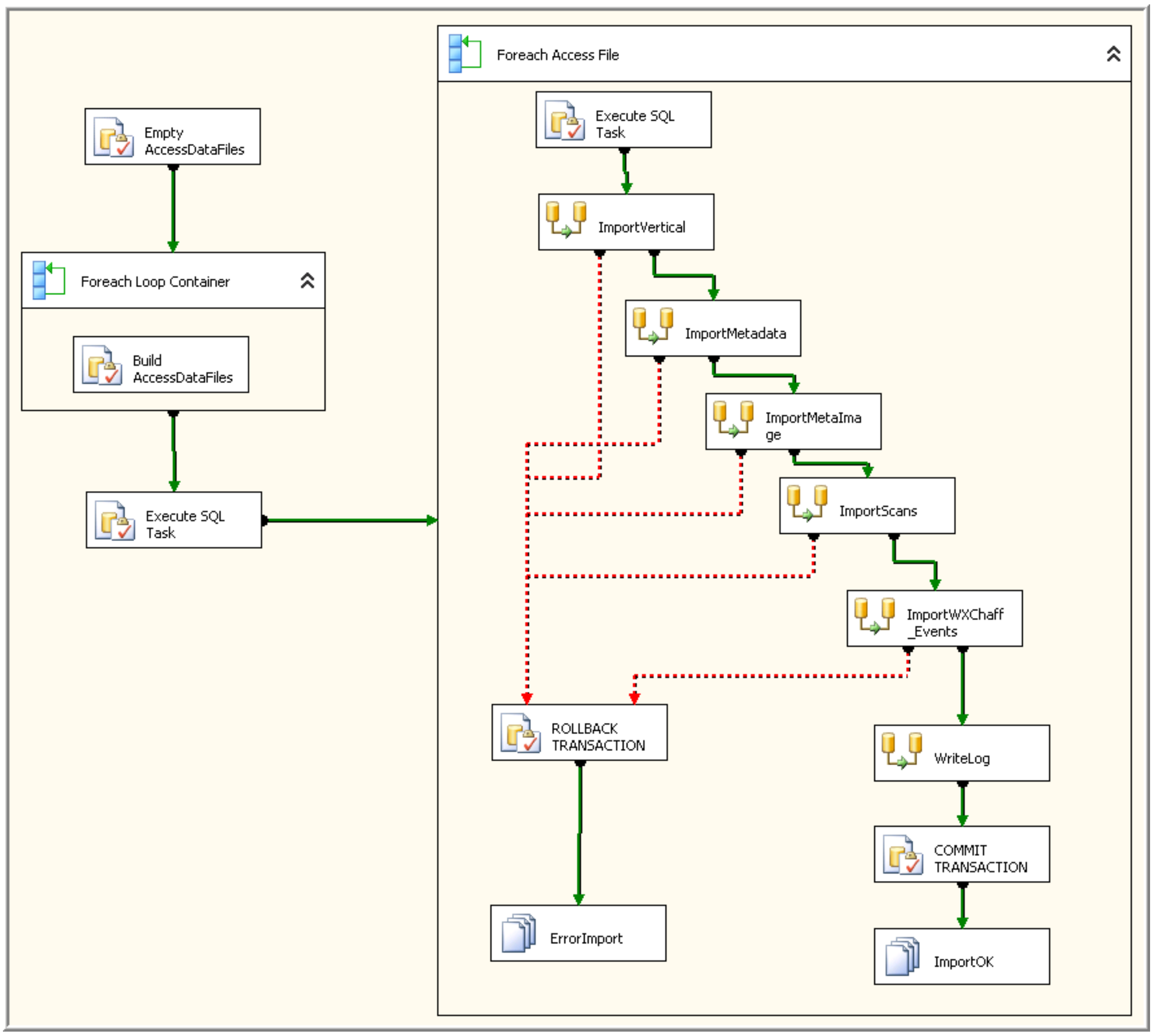

Figure 32. *Data import - SQL Server 2008 Integration Services.*

Figure 33. *Image showing approximate camera positions around wind turbine 43. Photo taken from “Gule Sider®”.*

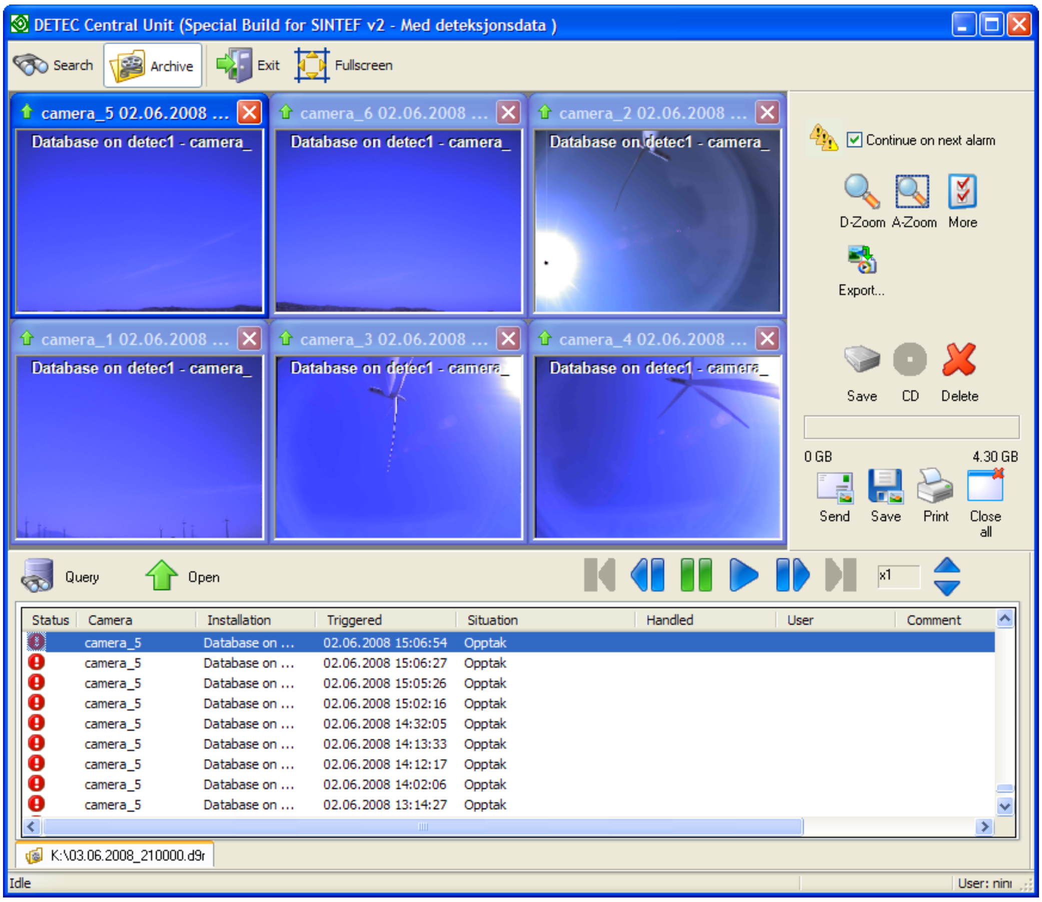

Figure 34. *Screenshot of DETEC Central unit, software to view recorded images.*

3.9 GIS and terrain modelling

Subproject responsibility: Frank Hanssen

3.9.1 MERLIN GIS-tools

One of the objectives of this project is to gather all MERLIN GIS-tools in a toolbox extension for use in ArcGIS desktop 9.x. The only tool developed in the MERLIN Toolbox so far is the "Sector map tool". This tool is designed to create user-adapted background maps for the MERLIN Horizontal radar interface. The MERLIN operator can design cartography and save the map as a 1024 x 1024 pixels JPG image for use in the MERLIN Software.

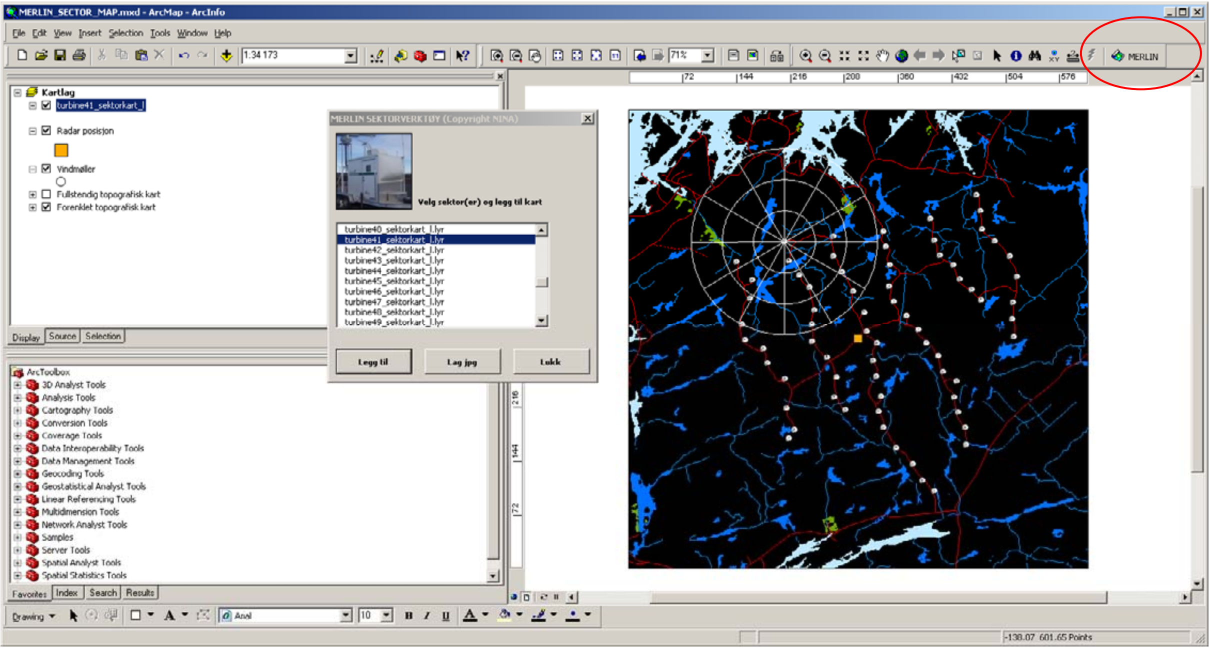

Figure 35. *MERLIN Sector Map Tool.*

For ground-thruthing purposes, predefined 30-degrees sectors at 500, 1000 and 1500 meters distances can easily be added to this background map. When the MERLIN operator observes potential bird tracks from a specific vantage point and sector distance in the MERLIN Horizontal radar interface, he/she can then immediately inform the ground-thruth personnel where to look for incoming birds.

3.9.2 Collision tracks analysis

We have recently started to develop a tool for analysing collision tracks in ArcGIS desktop. It should here be stated that the data-filtering procedures in the database still has to be improved with respect to clutter, rain and other errors that could be misinterpreted as bird tracks (i.e. false alarms).

The methodology for this analysis is established in ArcGIS Model-builder and will be implemented as a tool in the MERLIN Desktop Toolbox in the nearest future. The steps are briefly described below:

1. Track point data is accessed directly from the MERLIN Horizontal database.
2. All single track points are filtered out.
3. Tracks are created from track points using Track_ID and Date.
4. All tracks within a set distance (100 meter) from a specific wind turbine are selected.

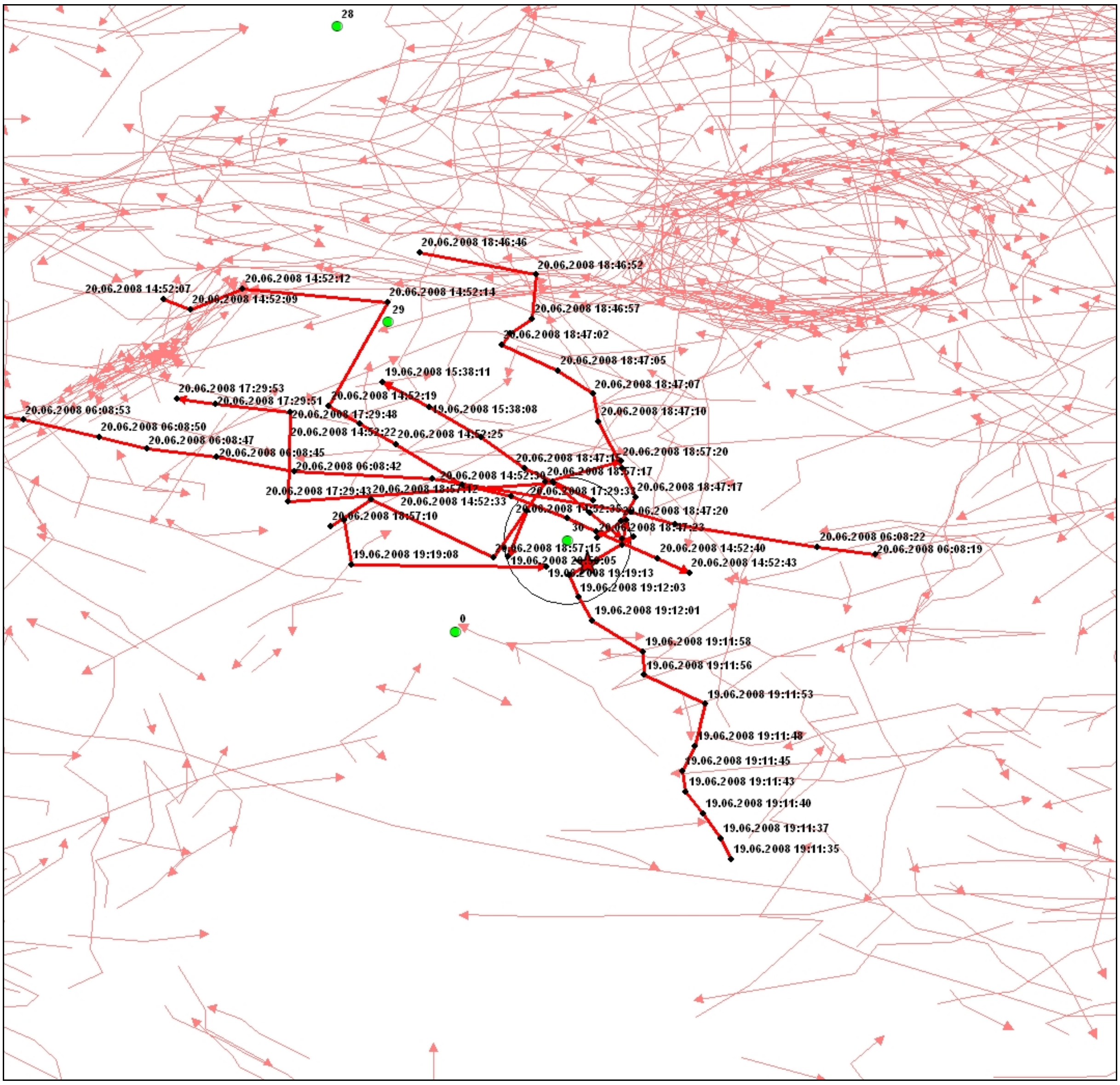

Figure 36. *Calculated tracks (from 19/6 19:06 – 20/6 18:47) within 100 meters distance (dark red line) from wind turbine number 30 (green dot symbol).Dark red star symbol indicates a collision where a dead white-tailed sea eagle was found.*

Interpreting radar data is likely to be difficult due to the sheer amount of recorded tracks, and potential false alarms (e.g. wind turbine interference, precipitation) misinterpreted as bird tracks by the MERLIN software processor. Figure 36 illustrates this problem very well and it is doubtful that all the tracks are actual bird tracks. We will focus more on this in our further work by ground-truthing MERLIN tracks in the field and establishing improved data filtering techniques in the MERLIN databases.

3.9.3 Terrain modelling

Terrain related analysis of bird radar data on Smøla requires a consistent digital elevation model (DEM) with high elevation resolution. The most detailed public available DEM in Norway (DTM25) is developed by the Norwegian Mapping Authority. This elevation model is derived from vector elevation data in the national N50 vector dataset. The DTM25 contain 25 x 25 meter elevation pixels in 100 x 100 km GRID tiles. The DTM25 has too low elevation resolution for our purposes and we have therefore started to develop a new DEM with higher elevation resolution.

Our new – though still immature - DEM is derived from preliminary high resolution vector elevation data established through the ongoing local mapping project “Geovekst Smøla”. This joint mapping project has divided the mapping area into different mapping classes using the Norwegian “FKB- standard” for mapping data.

The new DEM is established as a TIN (Triangulated Irregular Network. This is a vector data structure that partitions geographic space into contiguous, non-overlapping triangles. The vertices of each triangle are sample data points with x-, y-, and z-values. These sample points are connected by lines to form Delaunay triangles). The TIN is then converted to a GRID with 5 x 5 meter elevation pixels.

The local mapping project and its data are not yet finished. Also, different mapping classes with different elevation resolutions introduce further weaknesses in the model. Our new DEM has therefore to be further improved when complete elevation data is available. Despite these weaknesses our new model is considered to be more precise and detailed than the DTM25.

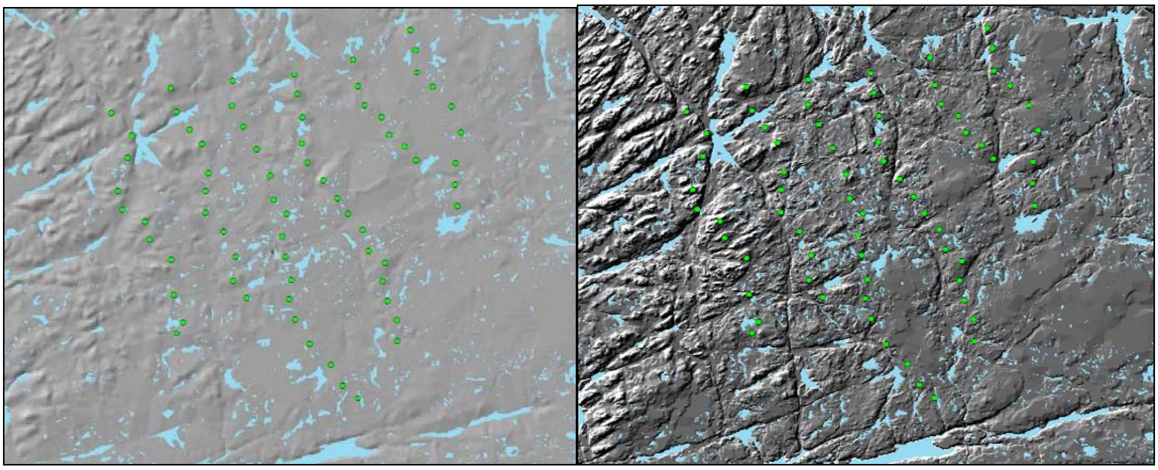

Figure 37. *Comparison of the DTM25 (to the left) and the new preliminary DEM (to the right) using hillshade.*

This autumn an airborne laser scanning project is initiated in the frame of “Geovekst Smøla”. Data from this laser scanning project will be delivered during December 2008 and will contain very detailed elevation information. These data could highly improve our DEM.

For visualisation and animation purposes we have downloaded digital aerial photos from the national image service “Norge i bilder” and draped them on to our new DEM. To improve the performance we will compress the images using MrSID- format or image caching techniques.

Figure 38. *Example of aerial image draped on to our new DEM. Elevation is exaggerated to give a better visual impression of the topography. Wind turbine number 21 in front.*

3.9.4 Modelling clutter and radar-coverage at different altitudes

The new DEM is so far in the project applied in modelling ground clutter and radar-coverage at different altitudes from the current MERLIN radar location. Both activities are performed within 2 nautical miles (defined as the MERLIN instrumented range) using viewshed analysis in Arc GIS 9.2 3D-analyst. Further inputs to the model described below are MERLIN radar antenna height (5 meters above ground), viewshed height (different altitudes above ground), vertical view angle (180 degrees) and horizontal view angle (360 degrees). Default settings for earth curvature and refractivity coefficient in Arc GIS 9.2 are currently applied in the model.

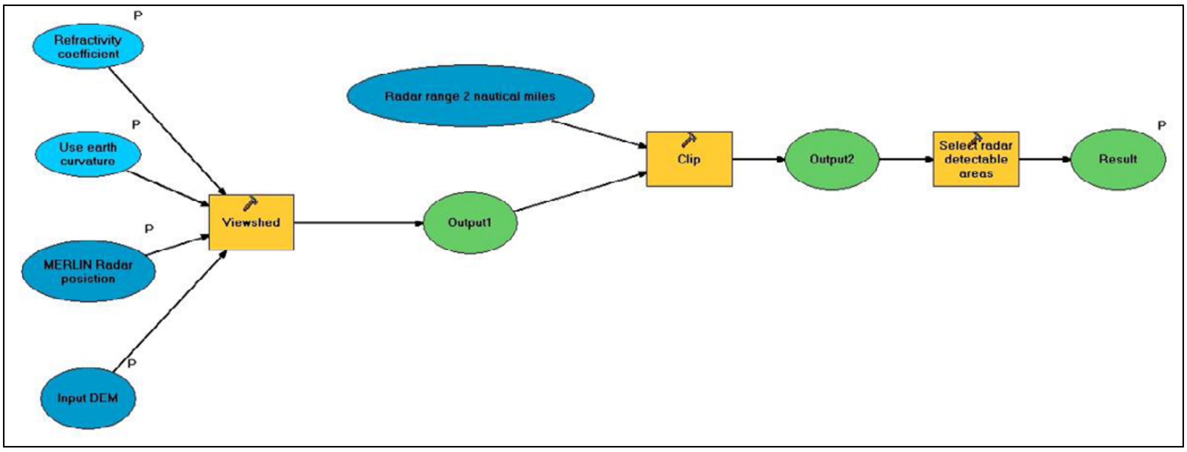

Figure 39. *Modelling ground clutter and radar coverage at different altitudes from a specific MERLIN radar location.*

The default refractivity coefficient used in Arc GIS is meant for visible light in ordinary viewshed analysis. This coefficient should in further clutter modelling be justified for MERLIN radar parameters, and atmospheric conditions. For microwaves at these frequencies it is usual to compensate for refraction by increasing the earth curvature with a factor of 4/3. The effect of this increased earth curvature will however be minor within the 2 nautical miles MERLIN instrumented range. To compensate for signal diffraction, radar resolution effects and inaccuracies in the DEM we decided to model ground clutter at 1 meter above ground.

This approach produces a map with potential clutter areas and radar coverage at different altitudes (see figure below).

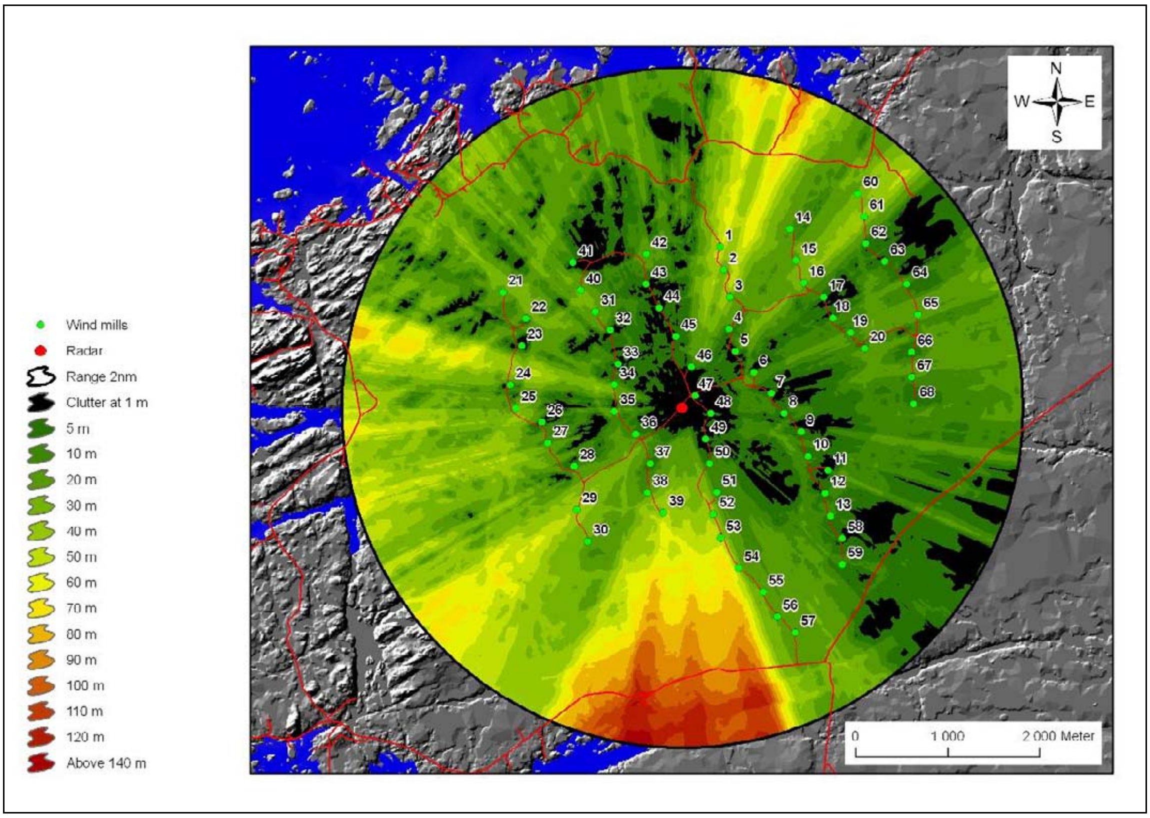

Figure 40. *Modelled ground clutter and radar-coverage at different altitudes.*

3.10 Bibliography - birds and aerial obstacles

Subproject responsibility: Torgeir Nygård

As a response to the request made by the Norwegian Water Resources and Energy Directorate, we have produced a bibliography on the relation between birds, bats, wind turbines and other aerial obstacles such as utility structures, towers and buildings. Earlier literature surveys at NINA facilitated the collection of older works, while extensive searches in on-line reference databases provided newer papers. Rather than the ordinary printed format, we chose a solution based on a web-version of EndNote. The database will be updated regularly, and is accessible via EndNote Web. At the date of printing it contains 1224 searchable references on these topics. Abstract is available for a large portion of the references. The database can also be used as a search engine for other databases such as ISI Web of knowledge, BIOSIS and others, depending on the access rights of the user. The database is named ”Birdwind” and is updated and administered by NINA, and the admittance is governed by the administrator, for the time being Torgeir Nygård.

A printed version is available from NINA as “Nygård, T., Bevanger, K. & Reitan, O. 2008. The relation between birds, wind turbines and other aerial obstacles. A literature survey. - NINA Report 413. 167 pp”.

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

4.1 Publications

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.

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.

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

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.

4.2 Lectures and conference participation

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.

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.

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.

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Follestad, A. & Flagstad, Ø. 2008. Preliminary results of Smøla white-tailed sea eagle DNA-analyses. - Wind Power Seminar at NINA 28 November. 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.
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Håstad, O. 2008. “The status of vision”. Årlig møte i Vindkraftprosjektet. - Havfiskesenteret, Smøla. 11-12 March 2008.
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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.
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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.

4.3 Coverage in public media

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

4.4 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.

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