NINA Report 355

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

Status report 1st January 2008

Kjetil Bevanger, Arne Follestad, Jan Ove Gjershaug, Duncan Halley, Frank Hanssen, Lars Johnsen, Roel May, Torgeir Nygård, Hans Christian Pedersen, Ole Reitan, Yngve Steinheim

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Norsk institutt for naturforskning

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Norwegian institute for nature research

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Wind turbines on Smøla. Photo Kjetil Bevanger

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Sammendrag

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NINA har siden 1999 hatt ulike forsknings- og utredningsaktiviteter knyttet til vindkraft og fugl (med spesiell fokus på havørn). Finansieringen har hovedsakelig kommet fra NVE og Statkraft, men også EBL, DN/MD, Norsk Hydro og RSPB (The Royal Society for the Protection of Birds) har bidratt. I juni 2006 sendte NINA søknaden *“Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway”* (et kompetanseprosjekt med brukermedvirkning - (KMB)) til Norges forskningsråd (NFR). NVE, Statkraft og EBL ga tilsagn om å bidra med til sammen vel 600 kkr årlig i prosjektperioden (2007-2010). MD/DN ga også uttrykk for at de støttet prosjektet, men reserverte seg mot å bidra økonomisk. I søknaden ble det lagt til grunn at aktivitetene som i 2006 var igangsatt, finansiert av Statkraft, skulle videreføres i prosjektperioden. I særlig grad gjaldt det innkjøp av radar og utvikling av annet teknisk utstyr for å teste ut mulige avbøtende tiltak. Budsjettet i NFR-prosjektet ble følgelig svært stramt lagt opp, og det var en forutsetning at den faglige gevinsten kunne komme gjennom synergier fra aktiviteter finansiert på bakgrunn av midler fra NFR-prosjektet og ekstra midler fra Statkraft og eventuelle andre aktører (f.eks. NVE, EBL og DN/MD). Ultimo desember 2006 ble det klart at NFR-prosjektet fikk finansiering på RENERGI-programmet. Rapporten summerer kort aktivitetene på ”paraplyprosjektet” i 2007. I alt er det igangsatt aktiviteter på 11 delprosjekt, mens 3 andre avventer finansiering. På grunn av forsinkelser i finansielle avklaringer ligger noe av aktivitetene noe bak den opprinnelige timeplanen og det vil derfor være aktuelt å vurdere en forlengelse av prosjektet med ca. et halvt år, dvs. frem til ca. 1. juli 2011. Det er ansatt en postdoc på prosjektet og tatt inn to mastergradsstudenter tilknyttet NTNU.

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Abstract

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”. A status report January 1 2008. – NINA Report 355: 33 pp.

NINA has since 1999 undertaken various research and investigation activities related to wind power generation and birds (with special focus on white-tailed sea eagles). Financial support has been provided principally by NVE (the government regulator) and Statkraft (an energy company), but also by EBL (the energy industry trade organisation), DN/MD (government environmental agency/department), Norsk Hydro, AMEC, (energy companies), and RSPB (a British environmental NGO). In June 2006 NINA submitted the funding application “*Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway”* (a capacity-building project with industry participation) to the Norwegian Research Council (NFR). NVE, Statkraft and EBL agreed to contribute supplementary funds amounting to 660 000 NOK annually in the project period (2007-2010). MD/DN has also voiced support for the project without committing funds. In the application it was established as a basis that the activities begun in 2006, financed by Statkraft, would be continued through the project period. This in particular concerned the purchase of radar equipment and development of other technical equipment to test possible methods to prevent bird strikes. The budget in the NFR project was in consequence very tightly precommitted, and it was a precondition that the research advances would come from activities financed on the basis of resources from the NFR project together with additional resources from Statkraft and possible other actors (e.g. NVE, EBL, and DN/MD). In late December 2006 it was confirmed that the project had received financing from the RENERGI programme. This report briefly summarises activities in the ‘umbrella project’ in 2007. In all, activities are underway in 11 subprojects, while 3 others await financing. Due to delays in obtaining clarification of funding levels, some of the activities are behind the original schedule and it will therefore be necessary to consider an extension of the project by about six months, to c. 1st July 2011. A postdoctoral researcher has been employed within the project, and two Masters students at the Norwegian Technical and Scientific University (NTNU) are attached to the project.

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Contents

Foreword

From 2007 inclusive, NINA has received economic support for research on wind power and birds through the Norwegian Research Council (NFR) though the project *Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway* of the RENERGI-programme. The project is a capacity building project with user participation (KMB). This has secured furtherance of the activities NINA has earlier carried out, among other places on Smøla, in connection with the wind park which Statkraft had obtained the concession to build. The NFR project has a comprehensive and challenging goal framework, as much economic as scientific, and can only be carried out through a close cooperation with energy and environmental management together with the construction side. In addition to the Norwegian Watershed and Energy Directorate (NVE), the Energy Producer's National Federation (EBL), and Statkraft at the outset committed themselves to contribute with an annual sum of 600 000kr to the NFR project, Statkraft has guaranteed considerable economic support for, among other things, the purchase of a specially constructed radar which will be operative in the first half of 2008. In the course of 2007, the environmental management authorities (MD and DN) and actors on the construction side signalled that that may be interested in contributing economically both to existing and new research modules under the umbrella of the NFR project. Support for elements of the programme has also been provided by the RSPB, a UK environmental NGO, and AMEC, a UK wind power generation company.

Trondheim, 5th January 2008

Kjetil Bevanger
Project leader

1 Introduction

NINA has, since 1999, carried out various research and review activities related to wind power and birds (with special focus on sea eagles). Finance has come principally from NVE and Statkraft, but also EBL, DN/MD, Norsk Hydro, RSPB and AMEC (Follestad et al. 2007).

With the background of the discovery of many sea eagles killed by the wind park on Smøla in the spring of 2006, NINA was invited to a meeting with Statkraft on 9th May 2006 to discuss development of our work with the wind power-bird problem. It was agreed that NINA, together with SINTEF, should prepare an outline pilot project proposal. The outline proposal, with economic framework, was sent to Statkraft on 20th June 2006. On the basis of verbal agreements, the following activities in the pilot project were begun:

- Search for dead birds under wind turbines with the help of specially trained dogs
- Video monitoring of activities at sea eagle
- Genetic analyses of feathers from sea eagles on Smøla

Activities related to population monitoring and behaviour of sea eagles were carried out with part-funding from NVE, Statkraft, and RSPB in 2006.

In June 2006 NINA submitted the application *"Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway"* (Appendix 1) (a capacity-building project with user participation) to the Norwegian Research Council (NFR). NVE, Statkraft, and EBL agreed to contribute a sum of over 600 000kr annually in the project period (2007), while MD/DN supported the project, but without committing to financial support.

The application writing process was predicated on the activities in Statkraft's pilot project being carried out as described in the project recommendation sent to Statkraft on 20.06.06, and that the economic obligations Statkraft had undertaken in this connection stood fast. The budget in the NFR project was very tightly circumscribed, and it was a precondition that the scientific progress must come from good synergies between funds from the NFR project and additional funds Statkraft and possible other actors (e.g. NVE, EBL, DN/MD) could contribute (in addition to their obligations under the NFR project). In late December 2006 it was confirmed that the NFR project would be funded by the RENERGI programme.

This report summarises briefly the activities in the project in 2007. Most subprojects are in progress, however some are behind schedule compared to the original time plan. It will therefore be necessary to consider an extension of the project by about 6 months, to c. 1st July 2011.

2 Meetings

Many important meetings were held in connection with the project in 2007; the content of selected meetings is summarised below.

2.1 Meeting with Statkraft 4th January 2007

The meeting was held at NINA eadquarters in Trondheim, with participation of Statkraft and project scientists from NINA and SINTEF. The meeting was a consideration of the status of the various activities specially financed by Statkraft, together with a discussion as to how further work should be organised in the light of the NFR project obtaining funding.

The meeting concluded, among other things, that Statkraft would finance a pilot study of radar together with possible technical solutions which might be possible to go further with, involving

audio and visual stimuli. This work was primarily carried out by SINTEF and the final report from SINTEF was sent to Statkraft on 24th April 2007. On the 15th of May 2007 NINA sent a note to Statkraft where, *inter alia,* an economic guarantee was requested to obtain a radar in accordance with the recommendation of the SINTEF report.

2.2 Meeting 6th February 2007 at NINAs offices in Trondheim

Organisations committed to contributing to the financing of the NFR-project were, together with DN and NFR, invited to participate in a meeting with participating researchers from NINA and SINTEF on 6th February 2007. Participants were: from **NINA**: Kjetil Bevanger (chairman, secretary), Eirin Bjørkvoll, Inga Bruteig, Arne Follestad, Duncan Halley, Torgeir Nygård, Hans Christian Pedersen, Ole Reitan; from **SINTEF:** Yngve Steinheim; from **DN**: Arild Espelien, Toril Grønningseter; from **NVE**: Lars Håkon Bjugan, Asle Selfors; from **EBL**: Hans Magne Ådland; from **STATKRAFT**: Per Christian Kittilsen, Tormod Schei. Harald Rikheim (**NFR**) had advised that he would be unable to attend.

The following agenda was discussed:

Summing up of last years' work financed by Statkraft/NVE and a review of activities undertaken in relation to the NFR project:
- *Sea eagle*
  - *Monitoring, genetics, behavioural studies, video monitoring of sea eagle eyries (Arne Follestad)*
  - *Radio telemetry (Torgeir Nygård)*
- *Other species*
  - *Willow grouse (Hans Christian Pedersen)*
  - *Greylag goose (Arne Follestad)*[1]
  - *Waders, ducks, divers (Duncan Halley)*
- *Search for dead birds (Ole Reitan)*
- *Radar, optical/auditory systems etc. (Yngve Steinheim)*

Discussion:
- *Are the activities underway in line with the needs/wishes of managment/developers*
- *budget*
  - *consultative committees' role, dissemination etc.*

2.2.1 Choice of species and research areas

NINA explained that the species which were planned to bethe focus of the study were,chosen, among other reasons, as representative model species for their respective bird groups. It should be possible to make more general statements about how wind power and collision problems can affect other species within the model species' group.

NVE pointed out the importance of maintaining focus on red-listed species, and not to be too general with respect to the wind power-bird problem. There was some discussion concerning economically important (game) species as opposed to red-listed species, among other reasons because compensation practice and concession practice are two different things. The concessionary authorities expect the results to say something about which areas wind turbines should not be located in due to concerns for vulnerable and threatened species, and which types of terrain and topographic elements should in that case be avoided. With regard to alternative research sites, Bessakerfjellet og Vikna were suggested as possibilities.

1.
[1] Greylag geese are temporarily removed from the project for financial reasons.

Statkraft recognised the importance of acquiring knowledge on a broad spectrum of bird species, not only red-listed, since such knowledge can contribute to less conflictual localisation of wind turbines in the future. This view received support from DN, which was interested in the occurrence of other bird species in the chosen research sites being mapped in conjunction with, e.g., census taking of waders and other wetland birds.

DN recommended that eagle owls should be included as a part of the investigation, as the species is listed as seriously threatened in the new Norwegian Red List (published 06.12.06). It was also indicated that the Smøla willow grouse is a special subject in that it is a subspecies of willow grouse, with a unique inheritance, and as such would have been considered a Red List species if subspecies problems were included in Red List designation. It is in addition Norway's only endemic subspecies.

Statkraft has been in contact with a developer in Great Britain (AMEC Wind Energy), which is interested in contributing to the development of a better knowledge platform on wind turbines and red-throated divers. NINA will follow up.

2.2.2 Budget

The budget of the NFR project is tight, and it has been necessary to prioritise both with respect to species and the scope of activities generally. However, as Statkraft has contributed considerable financial support it has been possible to get the programme underway, and much of the activity in the programme builds on Statkraft's contribution, both in 2007 and later.

EBL, Statkraft, and NINA are examining the possibilities of approaching EBL's members to strengthen the financing of those areas which are not currently sufficiently financed. The base financing that NFR now provides gives good possibilities for organising a diversity of activities such that desirable, but hard to attain, knowledge can be acquired, with significant synergistic effects.

NINA distributed an overview which included a tentative budget for 2007, in relation to the various activities and financial sources. Statkraft is assumed to contribute 1 620 000kr, NVE 200 000kr, EBL 100 000kr and DN 100 000kr. In addition to the economic pledges NVR has made through the NFR project (c. 200 000kr annually), it has been signalled that they will try to contribute with further funds, in the current year c. 200 000kr. Statkraft has earlier given verbal assurances that it will cover its proportion of the financing.

2.2.3 Dissemination

NINA presented information on planned methods of presenting results, and the expectations NFR has in this respect. I addition to publications in international journals, results from the project and other items of general interest will be presented in popular form through various media, including popular science magazines, newspapers, radio and TV. NINA will also establish a website for the project. NVE pointed out that they wished a policy oriented angle to the popular science presentations on the subject.

NVE expressed a wish for summaries of the activities in the last four years, which have largely focussed on sea eagles, to be produced in the form of a summary report together with a popular science presentation of the results, suitable for a broad public. NINA promised delivery by 1st April. Arne Follestad was responsible for preparation. This resulted in NINA Report 248: Vindkraft og fugl på Smøla 2003-2006 *(Wind power and birds on Smøla 2003-2006).*

2.2.4 Advisory group

Members of the advisory group will naturally consist of all those contributing to the NFR project, and it is intended to meet at least once a year. In addition it will be natural to hold formal and informal contact as required.

2.3 Kick-off-meeting on Smøla 26-27th March 2007

A two day scientific meeting was organised on Smøla, including a visit to the wind park and a review of the scientific activities of the NFR project. Economic requirements and scientific organisation were also discussed. The following persons participated: **NINA**: Kjetil Bevanger, Eirin Bjørkvoll, Arne Follestad, Duncan Halley, Torgeir Nygård, Hans Christian Pedersen, Ole Reitan. **SINTEF**: Lars Johnsen, Yngve Steinheim. **Danmarks Miljøundersøkelser (NERI)**: Mark Desholm. **University of Bristol/Uppsala**: Olle Håstad. **RSPB**: Rowena Langston; **STATKRAFT**: Tormod Schei.

The following contributions (with associated discussions) were made:

Lars Johnsen: Preliminary studies focusing bird vision
Yngve Steinheim: Preliminary studies focusing radar systems
Tormod Schei: Overview of the Statkraft activities
Arne Folelstad: White tailed sea eagle research at Smøla
Torgeir Nygård: Radiotagging white tailed sea eagle
Ole Reitan: Dead bird search
Eirin Bjørkvoll: PhD Thesis
Rowena Langston: Brief overview of RSPB activities
Hans Chr. Pedersen: Willow grouse and wind turbines
Duncan Halley: Wader populations: initial field strategy
Olle Håstad: Bird vision and wind farms – constraints and research need
Mark Desholm: Research on birds and wind farms in Denmark (focusing on radar and TADS)

Rowena Langston gives a talk at the Smøla meeting, 27th March 2007. Olle Håstad on the right.

Visit to Smøla wind park, 26th March 2007.

3 Contract agreement Statkraft-NINA

On the basis of earlier discusions between Statkraft and NINA, a contract between Statkraft and NINA was signe don the 29th June 2007. This provides for carrying forward part of the research and development activities related to birds and the wind power station on Smøla in the period 2007-2011. The contract provides for the following activities (and the associated financial framework):

- Purchase of radar
- Auditory/visual measures
- Weekly search for dead birds
- Development of detector systems/video surveillance
- Genetic studies of sea eagles
- Radio telemetry of sea eagles
- Behavioural response of sea eagles
- Contribution to the NFR-project

4 Engagement of doctoral student/postdoc

The employment of a doctoral student was required by the provisions of the NFR project. Eirin Bjørkvoll was engaged by the project in this capacity 15th February 2007. A project description giving the background to the study, research requirements, and budget was developed. The following working titles were planned for articles which would form part of the thesis:

- *Status and mortality factors of resident eagles in Norway (white-tailed sea eagle and golden eagle).*
- *Flying behaviour of white-tailed sea eagle at an on-shore wind farm in Norway.*
- *Assessments of avian collision rates at an on-shore wind farm on the basis of carcass search by trained dogs.*
- *Collision risk of white-tailed sea eagle resident at an on-shore wind farm.*
- *Population viability analysis of a white-tailed sea eagle population resident at an on-shore wind farm.*

Bjørkvoll collected literature dealing with, among other things, the general ecology of sea eagles; pollutants in sea eagles and other raptors; wind power generation on Smøla; methods of studying raptors in general and in connection with wind power generation; behavioural studies of birds in wind parks; searching for bird strike casualties with and without dogs; research issues with regard to power lines; telemetry; use of radar technology in a wind power generation context; collision models/risks; general effects of wind turbines on bird populations; PVA analyses; and general modelling.

Bjørkvoll worked on cleaning the data set collected in connection with sea eagle behaviour in the wind park, and restructured it to a form which allows obtaining an overview more easily. A number of appraisals of the potential for further work were carried out. Data was in part typed in again from scratch, where there were lacunae and errors in the data set in comparison with the original paper forms. A careful review of the data was made to determine the scope of the observations with regard to species, activity, and height. From this it was concluded that the best starting point for further analyses was to concentrate on sea eagles, and aerial activity. In addition, radar maps can be reviewed to exclude possible observations which are not within the wind park. As the data set currently exists, the only explanatory variable of the dataset which can be used is the time of the observation (which must be chosen on an appropriate scale)

Bjørkvoll informed the project in August that she did not wish to continue in the position, and NINA therefore applied to NFR to redefine the position as a postdoc. In a letter dated 3rd October 2007, NFR gave its consent to this change. NINA advertised the postdoc and received applications from 6 persons, one of whom was considered to be especially well qualified in relation to the demands of the position. However, the candidate withdrew his application after receiving an offer of the position. As none of the other applicants had skills which exceeded those already available within NINA, it was decided to recruit internally (Norwegian law requires that existing employees be redeployed to new work, if they are available and competent).

The post was offered to Dr. Roel May, who accepted. In the specifications for the postdoc especial weight was given to skills in population modelling, risk analyses, and statistical knowledge, to determine the population-level consequences increased mortality as a consequence of wind turbines will have for sea eagles. As none of the applicants, including Roel May, had this as a special competence, this part of the project will be carried out via closer cooperation with NTNU. Roel May will work especially with landscape analysis and GIS (together with Frank Hanssen i NINA), as we consider a development of this field will be central in the prediction of areas which should be avoided when wind power stations are established in the future. In addition he will have special responsibility related to the use of the bird radar.

5 Intake of Masters students

Pernille Lund Hoel was taken up as a Masters student within the project, and will have behavioural studies of sea eagles as her main focus of research. Although the materials collected earlier are now systematized and stored electronically, the collection methods employed have created problems with regard to further data analysis. Lund Hoel will begin fieldwork with an assistant in March 2008, collecting new data in a form which can be treated statistically. Data will be collected from the windpark itself and a control area outside the windpark. The research will be supervised by Eivin Røskaft and Bård Stokke at NTNU, and Kjetil Bevanger and Hans Christian Pedersen at NINA.

Espen Lie Dahl has also been taken up as a Masters student within the project, and will have the breeding biology of sea eagles as his main focus of research. The current working title of his thesis is “Do wind power developments affect breeding biology in White-tailed Sea Eagle *Haliaeetus albicilla*?” Supervisors are Eivin Røskaft and Bård Stokke at NTNU, and Torgeir Nygård at NINA.

6 Status of individual subprojects

6.1 Sea eagle telemetry

Goal: Use of satellite tags on sea eagles to learn more about the effects of wind turbines on sea eagles in connection with the wind park on Smøla.

The satellite tag marking programme has gone according to plan. Twelve sea eagle chicks were tagged at nests in and outside the wind park, ten of these with solar cell powered satellite tags and two with battery driven satellite tags, all with GPS units. One of these died shortly after fledging in an accident (caught fast in a dense bush beside the nest). One is missing, and may be dead. So far none have collided with wind turbines. Data is being collected continually, and will be digitised to map movement patterns, and later as part of a risk model.

In May/June 2007 all sea eagle territories on Smøla were mapped by Espen L. Dahl. Based on this survey, it was decided which pairs would be selected for tagging of young. Only one pair

was breeding within the wind park. As a result, only one chick from within the park could be satellite tagged, plus eleven from outside the park, but as near to it as possible. In the course of summer and autumn movement data was regularly downloaded via the internet and stored in a database. Before every search for dead birds in the park positions are checked to see whether any bird has not moved over a longer period (possible collision victim).

In 2008, marking of young will continue at about the same level as in 2007, with emphasis on satellite tagged sea eagle chicks born within, or so near as possible to, the park. Capture and satellite tagging of adult sea eagles is under consideration. This would require new permissions, and special capture equipment would have to be constructed. We nevertheless consider this aspect so important that we will work actively to achieve it, especially since most of the casualties have been adults. Torgeir Nygård is responsible for the project.

6.2 Weekly search for dead birds

Goal: To conduct regular searches for dead birds in the wind park as a basis for estimating species-specific collision risks.

Weekly searches with dogs were carried out, with a few exceptions (weeks 1,12,27,34, and 52). In one case in 2007 there were 13 days between searches, but in general searches were every 7 days (plus or minus one day). 25 ‘primary turbines’ were selected, which were searched every time, using a dog. Of these 17 were defined as ‘outer turbines’, and 8 as ‘inner turbines’ (the majority of collisions being with ‘outer turbines’, on the edge of the array). The other turbines are searched using a dog in selected weeks in periods with much bird activity. In addition all turbine locations were searched visually on every search day. The effectiveness of this strategy was estimated by a methodical check of how long a carcass remained lying beside a turbine, and by measuring the effectiveness of each of the dogs involved in the search. Visual searches were made during all driving along roads and turbine locations.

In the course of 2007, 29 dead individuals of at least 10 species were found. There were 15 dead **willow grouse**, of which at least 14 were considered at the site to be victims of collisions with wind turbines (plus one uncertain). Two dead **sea eagles** were found in 2007 (two finds were probably of parts of the same individual, but we await the final DNA analysis of these), both from the last days of April – beginning of May. Of waders, 3 **common snipe** and two **golden plover** were found. Single carcasses of **mallard, red-breasted merganser,** and **teal** were found. In addition, single carcasses of **little auk, fulmar** (alive), **meadow pipit,** and one unidentified bird, were found.

On average, 10-20% of the dead birds disappear every week, but bird remains can lie for a long time on Smøla. Search effectiveness is between 0.5 and 0.75 for the specially trained dogs, and between 0.4-0.5 for dogs generally trained in searching. Activities in 2008 will be as for 2007. Ole Reitan is responsible for the subproject.

6.3 Behavioural response of sea eagles

Goal: Learn more about how sea eagles respond behaviourally to different conditions in areas with wind turbines compared to areas without wind turbines – commencing with the wind park area on Smøla.

As a result of the NFR project, it has become possible to carry further the work already in progress in connection with the behavioural studies which were initiated and financed by the RSPB. The results are briefly summarised in NINA report 248. As stated under point 5, Eirin Bjørkvoll carried out an initial consideration/summary of the material. Pernille Lund Hoel will, in

her Masters thesis, work further on this theme (see chapter 5). Kjetil Bevanger is responsible for the subproject.

6.4 Genetic analyses of sea eagles

Goal: Carry out genetic investigations of breeding sea eagles on Smøla in order to calculate adult mortality among breeding sea eagles within and outwith the wind park.

The main goal of this project is to map adult mortality among established pairs which breed in, or close to, the wind park on Smøla, compared with pairs which breed at increasing differences from it. This will be done though genetic investigations of feathers which will be collected from young, and from shed feathers of adults collected in the vicinity of the nest. On the basis of such DNA analyses the following problems (among others) can be addressed:

a) Map where adults killed in collisions have their breeding territories.
b) Determine parentage of chick(s) in a nest. Together with similar investigations in later years, it can be determined whether it is still the same two birds who are the parents to new young or if a new partner has come in to the pair. This can indicate that one of the parent birds has died in the mean time. This gives data on adult mortality in the population, important data for modelling of both population dynamics and the risks connected to a wind park.
c) Genetic analyses of feathers can show whether young hatched within the park later establish as breeders.
d) Which birds establish in territories which are (considered to have been) abandoned by the original breeding birds.

Main activities in 2007 have been connected with the collection of material (feather samples of young in all nests with successful breeding on Smøla, together with moulted feathers from adult birds at or beside all nests where such feathers were found), treatment of samples from the collected material, and identification of DNA profiles. Analyses of the results will be performed early in 2008. Arne Follestad is responsible for the subproject.

6.5 Monitoring of breeding success in sea eagles.

Goal: Map changes in breeding population size and distribution on Smøla as a consequence of the construction of Smøla phases I and II, and how the wind park affects breeding success/reproduction both in the short and long term.

In a dense sea eagle population where alternative and optimal territories are lacking, changes over time will probably involve both a real population decline and reduced breeding success for pairs breeding in and near the wind park. The project will yield increased knowledge of site fidelity in sea eagles and how this can affect their attachment to nests/territories in or near the wind park. If sea eagles do not give up their territories, but continue to use them in the years after the wind park was completed, this may affect breeding success and expose the adults to an increased collision risk compared to attempting to establish themselves in another place. Emphasis is placed on mapping areas outwith the wind park to determine whether mew establishment of pairs will occur in or near the wind park when earlier occupied territories become vacant.

After fieldwork in 2007, the minimum population on Smøla was estimated to be 68 pairs. Territories which have been abandoned, of which there are 5 in the wind park area in which there have been no traces of activity in the last three years, are not included in this total. Three new territories were found in 2007, two in the outer islands and one near the wind parks' SW cor-

ner. In Smøla commune (local govt. district) 29 fledglings were produced in 2007. Only one pair produced a fledgling within the park in 2007. In total four successful breeding attempts have occurred in the wind park plan area since Stage I was built in 2002. Each was carried out by a different pair, that is to say no pair has so far produced more than one fledgling in the course of the last six breeding seasons. This low productivity within the wind park area in 2007 contrasts with productivity in the rest of Smøla kommune, which was better than for many years; production in the border zone to the wind park was also good. Arne Follestad is responsible for the subproject.

6.5.1 Removal of living sea eagle chicks for export

There has been some discussion in connection with NINAs participation in the attempt to build up self-sustaining populations of sea eagles in Scotland. The species became extinct in the British Isles c. 100 years ago. From the 1980s to the 1990s, Norwegian chicks were transported to the west coast of Scotland. These chicks came from the Bodø district and were collected by a local enthusiast. In order to spread species' range in Scotland and provide a new population nucleus, the Scottish nature protection authorities applied to the Norwegian authorities some years ago, wishing to obtain more sea eagles for a new release site on the east coast. When it became clear that the Scots wanted eagles from Norway in 2007, Alv Ottar Folkestad of the Norwegian Ornithological Society (NOF) took on the work. Young for Scotland were to be obtained from Møre & Romsdal, Sogn & Fjordane, and Hordaland.

Another group, led by Torgeir Nygård and Duncan Halley from NINA Trondheim, organised a parallel collection of sea eagle chicks for Ireland from Sør- & Nord-Trøndelag. These two groups have operated independently of each other in the collection process. Birds collected for Ireland were taken from areas outside the zone of influence for Smøla.

When in the course of collection it turned out to be difficult to obtain enough young in the south for Scotland, NOF decided to collect 7 eaglets, one from each of 7 twin broods, from Smøla's skerries and outer regions of 'mainland' Smøla (not from the wind park area). The effect of this removal must be included in the model when the sea eagle population's development due to local mortality is calculated. There is general agreement not to collect sea eagle chicks from the Smøla region in the years ahead, and a detailed discussion on how to carry out the collection in a manner involving the least 'noise' for the data for Smøla and the wind power project goals in this connection, will be important.

6.6 Bird radar

Goal: Purchase and development of radar as a tool for learning more about the effects of wind turbines on birds, in the first instance sea eagles, in connection with the wind park at Smøla.

The NFR project *Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway* was developed scientifically and in terms of budget from a background of discussions at the Stakraft meeting of 09.05.2006, where it was determined that the costs of radar and other technical equipment would be financed by Statkraft. It was further decided at the meeting that NINA, together with SINTEF, would develop an outline pilot project to obtain more knowledge of possible methods of reducing the danger of eagles being killed by the wind turbines. The pilot project was completed in the spring of 2007; SINTEF concluded that from time and economic considerations, it would be most realistic to invest in a commercially available mobile radar system specially designed for the purpose – Merlin, produced by the US firm DeTect.

Main activities in 2007 were related to determining which radar system would be most suitable for meeting the goals of the project. This part of the work culminated in late October with the

signing of a contract with DeTect for the purchase of a mobile radar system (Merlin Avian Radar System, Model XS2530e). The radar is delivered ready mounted on a car trailer and can easily be moved to the desired location.

The radar system ordered is expected to be delivered to Trondheim in late February 2008. A representative of DeTect will arrive in advance of delivery and begin work tailoring the computer equipment which will be installed in the radar to Norwegian conditions. The project radar expert, Yngve Steinheim from SINTEF, together with a representative from NINA, will visit DeTect headquarters in Florida in late January to approve the radar before it is sent to Norway ("Factory Acceptance Test (FAT)"). This in compliance with the contract where it is stated 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*".

On delivery and start up the producer will hold a two week course for the radar operators. After 90-180 days (flexible), a DeTect representative will again visit the radar and give any necessary additional instruction. It is intended to put the radar in full operation from a technical standpoint in the course of February-March 2008, so that the sea eagle breeding season can be covered and to provide initial experience in the use of the equipment. It is expected that it will be necessary to invest time throughout 2008 in developing further experience and knowledge in the use of the radar equipment, so as to optimise future methods of collecting and analysing data. Kjetil Bevanger and Yngve Steinheim are subproject leaders.

6.7 Detector and sensor systems

Goal: Development of equipment and technology for the detection of birds in the near vicinity of wind turbines, which can in future form the basis for developing methods for reducing the risk of birds being killed by wind turbines.

At the Statkraft meeting of 09.05.2006 it was agreed that NINA, together with SINTEF, should outline a pilot study aimed at obtaining more knowledge of visual/auditory techniques to reduce the danger that birds, including sea eagles, will be killed by the wind park. The project consisted of two parts, a literature review to determine previous attempts in this area (Reitan in press), together with a 'feasibility analysis' from a technical standpoint.

In its final report, submitted in April, SINTEF concluded that two new methods could be recommended:
- Camera based detection of birds and switching off of wind turbines
- Increased visibility through the use of UV-light sources mounted on rotor blades

After further discussions, the implementation phase of this work will consist of:

- Development and delivery of 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).

Main activities in 2007 have been related to determining which of the main themes should be prioritised given what seems most technically and biologically realistic, together with the allocation of resources to carry through the project. Most of the activity related to this project will take

place in 2008; according to the project plan SINTEF intends to deliver the equipment in the course of the first half of 2008. Kjetil Bevanger and Lars Johnsen are subproject leaders.

6.8 Auditory and visual measures

Goal: To provide advice in connection with the NFR project as to the degree to which it will be possible to develop preventive measures against collisions based on the hearing and vision of birds, employing contributions from among others Olle Håstad and SINTEF.

In connection with the goal of learning more about the degree to which bird vision in an important factor affecting various bird species' vulnerability to collisions, the subproject will employ expertise from Sweden (University of Uppsala/Bristol) and SINTEF. This part of the project has in the current year not had activities beyond the joint scientific meeting on Smøla 26.-27.03.2007. Statkraft has had contact with Olle Håstad and will contribute with separate financing of reseach activities in connection with an offshore wind power project in Sweden. It is intended to coordinate this activity with the NFR project on Smøla.

6.9 Waders and smaller passerines

Goal: Map the distribution of various wader and smaller passerine species in the wind park to determine to what degree the breeding population is affected by the physical location of wind turbines.

Thirty 1km transects were defined in the wind park area: 10 in the middle of the park, 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 park, and 10 to the west of the park in broken moorland resembling the western park. 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. Initial inspection of the data does not seem to indicate that population densities are greatly affected by turbine location. Further data analysis and statistical analyses are nevertheless necessary before secure conclusions can be drawn. Duncan Halley is responsible for the subproject.

6.10 Red-throated divers

Goal: Map the breeding population of red-throated divers on Smøla to determine whether the placing of wind turbines affects the wind park area's attractiveness as a breeding location compared with areas outwith the wind park.

NINA was contacted via Statkraft by the British power company AMEC Wind Energy Ltd., which expressed an interest in supporting research on red-throated divers. This formed the basis of a contract where NINA agreed to collect data on red-throated divers from Smøla. Results are summarised in NINA report 297 (Halley & Hopshaug 2007). The report gives an overview of the distribution and breeding success of the species on Smøla from 1999-2004, together with 2007. In the period September 2001-September 2002 the first phase of the wind park, 20 2MW turbines, was constructed. In the period October 2003-October 2005, phase two, consisting of a further 48 2.3 MW turbines, was constructed.

23 breeding localities for red-throated divers were located, of which up to 20 were in use in any one year, though 10-13 breeding attempts were more normal. Fledging success was 0.42/pair/year, similar to other coastal breeding populations of the species. Breeding success in 2007 was 0.15 fledglings/pair; however, it should be noted that large interannual fluctuations in breeding success are normal in this species, and it seems unlikely that the wind park affected breeding success in 2007 given that all registered breeding localities in that year were relatively distant from the wind park.

Three breeding localities were found within the wind park area, before the turbines were constructed. None of these have since been used. It is uncertain the degree to which this is due to the wind turbines themselves, increased disturbance due to easier access to the area through the road network constructed between the turbines, and/or continuing influence of the disturbance caused during the construction phase.

46 hours and 20 minutes of systematic field observations were made within the wind park area. In addition, considerable further observations of an unsystematic nature were made by other field personnel in the breeding season. Despite this, not a single observation of red throated divers was recorded. This may indicate an avoidance effect. At least four pairs breed in central areas of the island where the coastline on the far side of the turbine arrays is (by a small margin) the closest potential feeding area. So far, no red-throated divers have been recorded as collision casualties in the regular searches for dead birds. This, together with the fact that the species no longer breeds in – or crosses through – the wind park, indicates that the collision risk for the species at this site is very low.

Further studies of red-throated divers should include observations early in the breeding season to determine whether the species visits the wind park at that time. This will help in determining the degree to which the species may be able to resume breeding within the wind park area now that the disturbance from the construction period is over and access to the internal roads has been restricted. Observations should also be made of the direction of feeding flights from the breeding localities in the centre of the island, to determine whether these birds prefer to feed at particular locations, or fly to feed in all directions except those which would take them through the wind park. The latter would suggest active avoidance. Duncan Halley is responsible for the subproject.

6.11 Willow Grouse

Goal: Study the direct and indirect effects of wind turbines on grouse behaviour, habitat selection, reproduction, and survival in selected areas where wind turbines are established or planned.

The willow grouse population was censused in spring and autumn 1999 in connection with the environmental impact assessment ahead of the establishment of the wind park (Follestad et al. 1999). On the initiative of the Smøla landowners association, autumn counts have been contued thereafter. From autumn 2005 these censuses have formed part of a national scheme for game bird censusing; autumn populations and chick production have been estimated (Solvang et al. 2005). In the spring of 2007 the grouse population (density) in the wind park and in bordering reference areas without turbines were censused on 5-6th May using standard line transect methodology (DISTANCE). The same areas were used for censusing population density and chick production in the first week of august. Initial analyses indicate no clear differences in density between the two areas (windpark and reference) wither in spring or autumn. However, the data set, especially in autumn 2007, is too limited to draw clear conclusions. This can be rectified though widening the scope of censusing.

In autumn 2007, the census work was expanded with an august census on Hitra both in the wind park there on Eldsfjellet and in a reference area on Skårfjellet/Mørkdalstua. The area was

too small for standard transect methods to be appropriate. A modified form of DISTANCE was therefore used in both areas.

On Andøya in Troms an August census was attempted in an area where a wind park is planned. This proved to be impractical to organise in time, but a census of a potential reference area was carried out. Planning work has been carried out to prepare for census work in spring in both areas on Andøya.

Radio telemetry will be employed to investigate grouse behaviour, reproduction, habitat choice and survival. Initially this will only be practical on Smøla. However, it is difficult to trap grouse in snow free environments. The trapping method has been tested in the pre-Christmas period of 2007 with fairly positive results. This work will be carried forward in winter 2007-2008. Hans Christian Pedersen is responsible for the subproject .

6.12 Eagle owl

Goal: Obtain knowledge on the eagle owl's living pattern, area use, and population dynamics, in order to estimate the species' vulnerability in relation to wind power construction and related installations, as a basis for planning, carrying out, and evaluating amelioration measures.

Funding has been sought from EBL for an eagle owl subproject within the 'umbrella' of the wind power project financed by NFR.

The eagle owl is listed as 'seriously threatened' in the Norwegian Red List 2006. There has been a long-term population decline in Norway as in most other parts of Europe. Today, population development is positive in Germany and Sweden following a comprehensive programme of artificial rearing and release, together with concrete measures for reducing the most serious anthropogenic negative factors. Mortality caused by electrical installations (mainly electrocution) is well documented in a number of countries. In many countries, e.g. Sweden and Germany, constructive cooperation with power suppliers has been established and practical measures taken to eliminate dangerous installations, for example by insulating cables or constructing masts so that the electrocution danger is reduced. All evidence indicates electrocution is the most important cause of the species' steady population decline in Norway. Practical amelioration measures are therefore important for the energy sector in Norway as well.

Amelioration measures should be followed up by a monitoring project in which mortality can be documented and the effect of amelioration measures determined. This should include monitoring of survival in adults with the help of DNA analysis of feathers moulted at the breeding site. Survival of young birds can be studied using satellite tagging.

There is in addition a great need for research on the effects of wind power development on eagle owls. Six eagle owls are documented to have been killed by wind turbines in a limited area of Germany, and its near relative the "Great Horned Owl" (*Bubo virginianus*) has been killed by wind turbines in California. It is assumed that the sea eagle's greater flight activity renders it more vulnerable to wind turbines than the eagle owl; however, this assumption is somewhat insecure. The sea eagle is day active and should therefore be more able to detect wind turbines than the night active eagle owl, and so to avoid them. Knowledge is lacking in this area today. Radio telemetry can provide knowledge on eagle owl area use as related to windpower developments and other infrastructure. In addition, reproduction should be monitored in the same area. Together these will provide information which can be used in a population mdel in a similar manner to the work on sea eagles now underway on Smøla.

The project will be carried out on the Helgeland coast, which has Norway's densest eagle owl population, and which has been monitored for a number of years. Information is available on the numbers of eagle owls killed by power lines, and the area is considered the best available

for determining the effect of amelioration measures. A windfarm is planned for the area (Sleneset). For further discussion of eagle owls, see NINA Reports 239 og 264; "Hubro på Karmøya og vindkraft" and "Hubro på Sleneset og vindkraft" (Norwegian with English abstract). Jan Ove Gjershaug will be the subproject leader.

6.13 Golden eagle

Goal: Identify areas often used by golden eagles and estimate the effects of possible wind power development in selected areas.

Funding has been sought from EBL for a project on golden eagles within the 'umbrella' of the wind power project financed by NFR.

Much of the research results so far obtained, in Norway and internationally, indicates that certain raptor species are especially vulnerable to being killed by wind turbines. The golden eagle is listed as 'near threatened' in the Norwegian Red List 2006. Experience from Altamont Pass in California demonstrates that the species is vulnerable to wind power development; in Great Britain there has also been considerable discussion of the vulnerability of the species to wind power development. In mid-Norway, plans have been made for many wind power stations in mountain areas with relatively many golden eagles, among others in the kommunes Agdenes (Hestgrovheia), Orkdal (Vargheia) and Snillfjord (Geitfjellet, Svarthammaren, Tannvikfjella og Remmafjellet). In these areas NINA has carried out monitoring of breeding sites for the Provincial Governor of Sør-Trøndelag; 7 localities are known so far. Observations indicate that golden eagles use the open mountain areas between fjords for hunting, but satellite telemetry of particular individuals will be necessary to refine this knowledge. It will then be possible to say more about which areas should be avoided to reduce wind turbine/golden eagle conflicts as much as possible. The Provincial Governor of Sør-Trøndelag has indicated that such a project would be of considerable interest. Jan Ove Gjershaug will be subproject leader.

6.14 Data flow, visualisation, and modelling

Goal: Operationalise data collected from radar monitoring/radio telemetry, visualise individual's movement patterns in 3D and establish methodologies for and model potential conflict areas between birds and wind power stations.

Funding has been sought from EBL for a project on data flow, visualisation, and modelling within the 'umbrella' of the wind power project financed by NFR.

The data flow from radar monitoring/radio telemetry will be made as dynamic as possible (as near real-time as possible) and stored in a separate database base don a SQL server 2005/ArcSDE or equivalent. The data will be made available in a WEB-based map suite (2D maps) to give a complete overview of the affected individuals' movement patterns. The 2D maps will be searchable for species, sex, time period, etc.

Individual's movement patterns will be visualised in a 3D terrain model. This can be done at various levels from prepared animations (performed by ArcGIS desktop or equivalent) to dynamic web-map applications in 3D with a greater degree of user steering (based on ArcGIS Server or equivalent)

On the basis of collected data on movement patterns and terrain models / maps, methods for the weighting of various topographic barriers/installations which function as a hindrance for individuals' movement patterns will be developed. These will be modelled in GIS to highlight potential conflict areas where wind power developments should be avoided. Frank Hanssen is responsible for the subproject.

7 Further work

2008 will be a year involving considerable data collection activity. A considerable challenge will be learning to use the bird radar, which it is hoped will contribute to data collection beginning in March. We will also approach the Avinor (Norwegian air traffic control) and/or Air Defence radar systems to determine whether they may be used for analysis of bird migration in 2008.

We are in contact with Statkraft to put in place temporary accommodation with overnight facilities and laboratory space next to Statkraft's operations centre within the wind park. This will also be the storage site for the mobile radar. Roel May will have responsibility for establishing a website for the project so that interested parties can keep themselves oriented about the programme. A scientific meeting is planned on Smøla in March, combined with a meeting where representatives from the contributors to the NFR project will participate.

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

8.1 Publications

Bevanger, K. 2007. Vindkraft og miljø. – NINA Årsmelding 2006: 6. *(with English summary)*

Follestad, A., Reitan, O., Nygård, T., Flagstad, Ø. & Schulze, J. 2007. Vindkraft og fugl på Smøla 2003-2006. - NINA Report 248. 74 pp. *(with English summary)*

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

Reitan, O. (i trykk). Tiltak for å redusere dødelighet hos fugl ved vindmøller: En litteraturgjennomgang av visuelle og auditive aspekter. - NINA Report. *(with English summary)*

8.2 Lectures and conference participation

Bevanger, K. 2007. Vindkraft og fugl. – Lecture at Produksjonsteknisk konferanse EBL, Gardermoen 7th March.

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

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

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

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

Follestad, A. 2007. Smøla wind farm and white-tailed eagles. – Lecture to the South African delegation visiting DN/MD 17th October.

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

Nygård, T. 2007. Satellittstudier av unge havørners bevegelser i vindparkområdet på Smøla. Lecture. Scientific meeting on windpower. Smøla. 26-27th March.

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

Nygård, T., Follestad, A., Reitan, O. & Dahl, E.L. 2007. Kartlegging av unge havørners bevegelser på Smøla ved bruk av satellittelemetri. - Kungsörnsymposium. Holmhallar, Gotland, Sweden. 28th September.
Reitan, O. 2007. Søk etter døde ørner i vindparken på Smøla. Statkraft medarbeidermøte, Smøla. 29th August.
Reitan, O. 2007. Vindkraft og havørn. Medarbeiderseminar for Veterinærinstituttene. Trondheim. 25th September.
Reitan, O. 2007. Vindkraft og havørn. Kungsörnsymposium, Holmhällar, Gotland. 28th September.
Steinheim, Y. International Conference and Workshop on Radar Ornithology and Entomology 25-28th June 2007. Helgoland, Germany.

8.3 Coverage in public media

NRK TV (national): Schrødingers katt, 19th April 2007. On wind turbines at sea (Arne Follestad).
NRK Radio (local): Møre og Romsdal 29th June 2007. Wind power and sea eagles (Arne Follestad)
NRK TV (local): Møre og Romsdal local 9th May 2007. Discovery of new eagle under wind turbine. Interview in the field on Smøla. (Ole Reitan).
A-Magasinet (magazine) 20. april 2007. Sniffing up dead eagles (Ole Reitan, Kjetil Bevanger)

9 Appendices

Appendix 1. Project description, NFR-project “Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway”.

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

A project proposal to “RENERGI”, the Norwegian Research Council, 8 June 2006

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PART 1: The KMB project

1 Objectives

Obtain an improved information base and tools for the energy industry and environmental and energy authorities to use in determining siting and conflict reduction of new wind turbine projects.

Subgoal Identify the biological, species specific, ecological and external factors which make birds vulnerable to wind turbines (e.g. manoeuvrability, aerodynamic constraints, visual perception, hunting techniques, bird age, habituation, nesting, feeding, local movement patterns, light and weather conditions, topography and wind turbine location in relation to major and local flyways), and assess the population consequences of wind turbine induced bird mortality.

2 Frontiers of knowledge and technology

Energy from renewable sources has become increasingly important as part of energy policies in Europe (Mitchell 2006), partly due to climate change scenarios from, e.g., the UN expert panel on climate change (http://www.ipcc.ch/). For several European countries wind power is the most promising renewable energy source. In modern history Norway has been a net exporter of renewable energy from hydropower production to various European countries. However, after recent periods requiring energy import, the Norwegian government has set a wind power target of 3 TWh annually by 2010 (The Sem Declaration). The potential for wind-power generation in Norway is far higher, and of added economic significance as Norwegian industry has the possibility to contribute to construction both as subcontractors and producers of complete wind power plants.

On several occasions energy and environmental management authorities, as well as the energy industry, have stressed the need for additional knowledge about environmental impacts, and how birds and animals respond to these man-made structures (e.g. NVE et al. 2003). Research on how wind turbines affect birds (and bats) has been conducted elsewhere for 10-20 years. However, the results have been inconsistent, and the numbers of casualties recorded differ widely between wind turbine plants and species. A limited number of studies have reported wind turbines to be less harmful than other structures including those connected to energy production (Nelson & Curry 1995, Osborn et al. 1998, Garthe & Hüppop 2004). Con-

versely, other studies have reported a significant number of birds being killed by wind turbine constructions (Orloff & Flannery 1992, Hunt et al. 1998). Overall, few rigorous scientific studies of the effects of wind turbines on ecosystem elements and function have as yet been made (Larsen & Madsen 2000, Osborn et al. 2000, Barrios & Rodriguez 2004, Desholm & Kahlert 2005), the majority being "grey" literature consisting of technical reports. However, the problem of bird mortality related to wind turbines has gained increasing international attention as the number of installations has increased, including (among other developments) the convening of an international conference on the problem in Leicester, April 2005 (Langston et al. 2006).

Few reports dealing with avian problems associated with wind turbine power plants relate to Norwegian conditions (e.g. Reitan & Follestad 2001, NVE et al. 2003). Moreover, data and experience from other countries may not be applicable to Norwegian coastal ecosystems due to important differences in fauna and topography (DN 2000). Mortality may not be due entirely to physical collisions. In six of 14 nocturnal accidents birds were swept down by the wake behind the rotor (Winkelman 1992). Mechanical and aerodynamic constraints among birds, as well as thermal and wind effects (e.g. Pennycuick 2002), in combination with turbine turbulence vortices, may be a problem both for soaring birds such as eagles, and to birds performing courtship or song flights in the air. During the period October 2005 - May 2006 nine dead white-tailed sea eagles (and some other birds) have been found killed in collisions at a single wind turbine plant - Norway's first large-scale wind turbine plant at Smøla, Central Norway (NINA, RSPB & Statkraft unpublished data).

Offshore, marine wind turbine plants have been a reality in Europe since the early 1990s (e.g. Desholm et al. 2006, Hüppop et al. 2006). In 2004 the first application for offshore wind power plants in Norway was sent to the Norwegian Water Resources and Energy Directorate (NVE) (http://www.nve.no/modules/module_111/netbasNVE.asp?script=8). This development creates yet another perspective for knowledge needs, as shallow water areas suitable for wind turbines may conflict with the feeding grounds and migratory routes of huge numbers of seabirds and coastal birds. These birds, resident as well as migratory, use the marine environment as a source of food, at the same time being dependent on land for e.g. nesting purposes. Moreover, large numbers of migratory birds navigate along the Norwegian coastline during their seasonal movements. Consequently, offshore wind turbines and wind turbines arranged along wind-exposed coastlines may affect a number of coastal species.

In contrast to the meagre existing information on wind turbines and birds, a significant body of knowledge on birds and collisions with power lines has been built up over the past 30 years. Although power lines are secondary constructions to wind turbines, there are several aspects of avian interactions with these constructions that may be used to understand, and perhaps mitigate, problems connected to wind turbines. A main conclusion from recent research connected to power lines and birds is that the problem is highly species specific, and most aspects of problems relating to avian mortality caused by power lines are not appropriate for broad generalisations (Bevanger 1993, 1994a, b, 1998, Bevanger & Brøseth 2001, 2004, Janss 2000). The same may apply to birds and wind turbines.

The overarching goal of the present study is to assess the effect of wind turbines on coastal bird population dynamics, as well as tools to be used for mitigating purposes both in connection to pre- and post construction wind turbine plants.

3 Research tasks

The main focus of the project is twofold: obtaining biological and ecological knowledge on wind turbines and bird behaviour, mortality and mitigating measures; and "tool development" to facilitate data collection.

Most bird species are prisoners of their evolutionary pasts in that they are fitted for a life in airspace without artificial obstacles. Their ability to learn and adapt to man made constructions erected in the airspace is limited. The extent of, and reasons for bird mortality in connection with other types of air obstacles like power lines and windows, are fairly well documented and understood. However, the causes of bird mortalities connected to wind turbine rotor blades are still poorly understood. They may for instance be connected to the fact that the rotor blades create wind vortices and aerodynamic constraints, but may also be connected to visual perception, and problems in seeing the rotor blades at close range.

Different bird species exhibit a wide range of behavioural adaptations which may make them more or less vulnerable to air obstacles. For example, species with aerial courtship displays during the breeding season, and/or special feeding, courtship and rival fighting behaviours may be more vulnerable than ground dwelling species. Moreover, inexperienced young birds may be more vulnerable to collisions with wind turbines than older, experienced individuals. Season, weather and light conditions are other factors thought to be important in influencing the likelihood of bird collisions with wind turbines. It is also logical to assume that wind turbine plants located close to important functional areas and migratory highways increase collision risk. The main data collecting and research elements in the project are, therefore, to record the overall impact of wind turbines on bird behaviour and mortality, and to evaluate and model the risk and population consequences of such mortality.

As different bird groups are thought to be susceptible to air obstacles in varying ways (Bevanger 1998), we have selected for study species within groups of differing aerodynamic abilities (mainly due to differences in wing morphology and body weight (Rayner 1988)). In the "poor flyer" group we have selected willow grouse (*Lagopus lagopus*), a resident species only performing local movements. Among typical wetland species we have selected geese, swans and waders. Predators/thermal soarers are covered by the ongoing project focusing on white tailed sea eagle. Some of the selected species are either of conservation concern (on the Norwegian red list) or of social and economic importance as small game resources.

The extent, to which it is possible to stimulate the sense organs of birds (eyes and/or ears) to make wind turbines more perceptible, so that the birds are able to avoid them, is currently an open question. As we have access to the wind turbines at Smøla, which are owned by one of the partners (Statkraft) for *in situ* experiments, we will be able to test mitigating measures that may be developed as alternatives to removing "problem" wind turbines.

The project will incorporate and use existing knowledge as the basis for its activities. The research will also incorporate and develop new techniques to answer biological questions. The technical co-partners have advanced knowledge on e.g. radar technology, and perception physiology. The project has therefore significant innovative potential and will both be a major contribution to the understanding of how birds are affected by wind power turbines as well as to the development of mitigating measures.

The study will incorporate one PhD-student, focusing on the development of statistical models for estimating the number of bird-turbine collisions at onshore wind farms, and the development of theoretical population models for assessing the impact from turbine-related mortality on avian population dynamics. The PhD-study will be advertised publicly, and the candidate will be formally associated with the Norwegian Institute for Nature Research, at the Trondheim Office.

PhD-project description

The first part of the PhD project aims at constructing statistical collision models for estimating the number of collisions between birds and wind turbines, given different bird species and wind farm scenarios. The turbine related variables for the collision models will include the physical structure and the "visibility" of the turbines, and their geographical siting.

The bird-related variables for the collision models comprise the species-specific migration patterns of the birds and their spatial response to the turbines. Tracking of migratory and resident birds will be accomplished by surveillance radar and radio telemetry. The variables for the collision models include e.g. topography, wind speed, and wind direction, which influence avian migration speed and course, and the rotation of the turbine blades (orientation and revolution speed). Additionally, the effect of changes in visibility will be included, as this is likely to alter both local migration and movement patterns, and the species-specific risk of collision.

The measurement of species-specific collision rates of birds passing close to the turbines is a key-variable for model validation, and will be assessed using a Thermal Animal Detection System (TADS) (Desholm 2003), a remote controlled infrared video recording system.

The second part of the PhD-study aims to develop theoretical models describing the population dynamic for different bird species. On the basis of age structured projection matrices (Leslie 1945, Caswell 1989), the relative elasticity and sensitivity of different age-specific demographic matrix elements will be estimated (de Kroon 1986, Benton & Grant 1999, Mills et al.

1999) and related to the growth rate. Such population models are valuable for the environmental agencies, since the effects of different human activities can be modelled, and hence, predictions about specific scenarios can be offered before an environmental planning decision is taken.

In the first instance, a complex matrix population model describing the life history of the white-tailed sea eagle will be developed. It is only for well-studied species like the white-tailed sea eagle that possible density-dependent relationships can be evaluated through retrospective analysis. The modelling work on the white-tailed sea eagle aims to specifically assess the effects of wind turbine power plants in Norwegian marine waters on this species.

4 Research approach, methods

The biological characteristics of a bird species, interactions with other faunal and vegetational elements, the topography of the area, and varying meteorological conditions are all factors that can easily influence the results of a study focusing on the impact of wind turbines on bird behaviour and mortality. The relationship between birds and wind turbines is probably not usefully captured by broad generalisations, and there are obvious constraints with regard to the level at which methods can be standardised. Methodological aspects should therefore be carefully assessed on a local scale. The suitability of the methods will be continuously assessed and if necessary, modified. The applied methods are grouped according to purpose, and the technical parts of the study reflect the importance of tool development to answer the biological questions.

A Bird behaviour and mortality studies

Searches for injured or dead victims at or near wind turbines are necessary to assess the number of victims and identify the species. A study addressing this research area is in progress. A pointer dog is under training and will be used to find dead birds. The methods and search regime will be in accordance with standards earlier developed for dead bird searches below power lines (see Bevanger 1999 for review) and wind turbines (Anderson et al. 1999, Smallwood & Thelander 2004).

The focus of the present study will be the use of radio transmitters to collect additional data enabling estimates of mortality within a specific population. Data on willow grouse population size will be recorded using line transects in spring (breeding population) and autumn, and autumn density will be calculated using the DISTANCE method (Buckland et al. 2001). The use of the wind turbine area by willow grouse will be studied by radio telemetry, both for breeding (some re-occupation of the breeding area?) and feeding (do they have any avoidance distance from turbines?). Willow grouse will be caught in winter by dazzling or netted using pointer dogs in early autumn.

A Thermal Animal Detection System (TADS) for automatic collision detection and estimating collision frequency, specific avoidance behaviour, detection of birds that are injured associated with e.g. turbulence vortices, night time species composition, flock sizes, and flight altitudes (Desholm et al. 2003) will be used to supplement the other methods.

Problems associated with statistical treatment and theoretical considerations of population impact inherent with small data sets and many environmental and ecological variables are complex, and require a detailed examination. The PhD-student will have this part of the study as the main focus, and closely co-operate with experts on population dynamics at the Norwegian University of Science and Technology in Trondheim (NTNU).

B Use of radar to collect data on bird behaviour and major and local flyways

Radar methods of recording the direction and numbers of birds migrating through the wind turbine area will be employed. The information obtained from radar will be particularly important in estimating collision risk. The data will be analysed for differences in bird migration during varying light and weather conditions. These measurements are necessary to obtain informative statistics on the frequency of collisions. Knowledge of the use of radar technology for these types of observations is particularly strong among our Danish partners (Desholm et al. 2005).

In the second stage, focus will be extended to the patterns of bird migration both at a large scale (spring and autumn migration) and local scale (movements between feeding areas and breeding areas and roosts). Bird migration patterns along the coast, in particular where and

how islands or peninsulas are crossed, forms an important area of knowledge in connection to decisions on future wind turbine locations. It is important to develop methods for cost-effective conflict mapping of areas meteorologically and topographically suitable for wind turbine plants. Radar has proved to be an efficient tool for mapping bird flyways.

A feasibility and preliminary study, initiated by the Smøla wind-farm operator, Statkraft, will among other elements focus on radar technology. Initial radar equipment will be purchased during the preliminary study, and the present project proposal is based on the preliminary study in the sense that basic equipment and knowledge already is in place by 2007. Thus, use of an automatic system for data collection, storage, and interpretation will be an important part of the radar study. Radar tracks will be stored in a format enabling the researcher to import it into a GIS tool and draw out different parameters for further statistical analyses, as well as 3D visualisation in terrain models.

The possibility to use radar data from the long range air defence radars of the Royal Norwegian Airforce, the Air Traffic Control radars of Avinor, and the Doppler weather radars of the Norwegian Meteorological Institute, to track large scale migration, will be investigated. If this is feasible, radar data from these systems will be an important source of information to map large scale migration.

C Deterrent and mitigating measures

Test and development of deterrent measures will focus on visual and auditory stimuli, or a combination of both. Every animal that has been tested (mammal, fish, insect or, in the case of birds, pigeons) has motion-sensitivity that is greatest at long wavelengths. In humans, motion detection is driven by the L+M cone response (i.e. luminance pathway); in bees it is the MW (green) receptors (i.e. the longest wavelengths to which they are sensitive); in birds it is consistent with the double cone response. UV-coatings are likely to be fairly unimportant for increasing the visibility of moving objects like wind turbine rotor blades (cfr. Young et al. 2003, I. Cuthill pers. comm.).

It is, however, possible to make the blades more visible to birds, by minimizing motion smear. Experimental laboratory studies indicate that painting one of the rotor blades black, or with a certain black striped pattern, may help to decrease the motion blur (cfr. Hodos 2003). A full scale experiment using wind turbines at Smøla will be carried out to test whether this will reduce the bird collision rate or affect bird flight behaviour.

The preliminary study (cfr. the radar studies in section B) will also include a feasibility study and tool development in connection TADS/IR. Moreover, a State of the art will be part of the preliminary study, making the basic for further work on deterrent measures focusing visual and auditory stimuli. The literature is quite voluminous regarding bird deterrent measures developed and used in connection to e.g. airports, crop protection and power lines. However, a majority of the studies performed have not been species specific and based on scientific studies and *in situ* experiments.

5 Project organisation and management

The project is constructed around three functional groups: regulatory (environmental and energy - the Directorate for Nature Management and the Norwegian Water Resources and Energy Directorate respectively), research (ecological and technological), industrial (the wind energy industry). Together these partners have the best qualifications to identify and mitigate the main conflicts between birds and wind power development revealed in recent years. To secure the interests of all sectors, the project will appoint a project group with selected members from each contributing partner, and meet regularly to discuss progress and project management.

NINA will be the lead institution for the project, with Dr. Kjetil Bevanger as project manager. The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology (SINTEF) has the necessary competence within radar technology, as well as visual and auditory science and will be the main co-partner for experimental design and in project execution. In addition to the PhD-student, masters students from the Norwegian University of Science and Technology (NTNU) will be invited to participate in the project. The project will be in close co-operation with Statkraft, the second largest producer of renewable energy in Europe. Experimental facilities *in situ* will be supported by them. In addition, the Norwegian Electricity Industry

Association (EBL), will be an important co-partner. The association has several members currently planning wind power development.

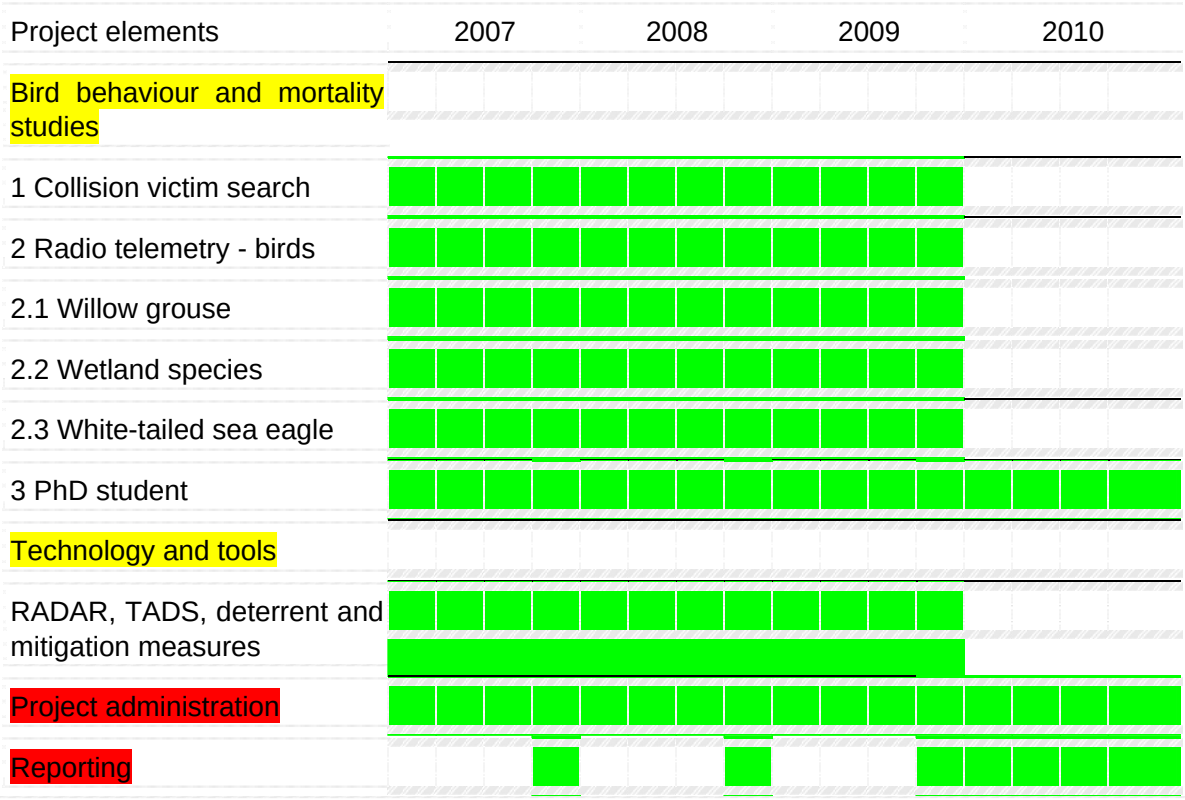
6 International co-operation

The project will be carried out in close collaboration with European institutions and experts onin fields relevant to birds and wind turbines. The National Environmental Research Institute in Denmark is the world leader in radar and TADS studies of bird movements at wind power plants. Experts on bird vision and bird flight and animal locomotion at the University of Bristol, and at the University of Uppsala in Sweden, will act as scientific advisers during the project period. The RSPB (the Royal Society for the Protection of Birds) is the leading conservation NGO in Europe in bird/wind turbine studies, co-funds behavioural studies in the ongoing white tailed sea-eagle project at Smøla and will be an important co-partner in this programme.

7 Progress plan – milestones

Project start is scheduled for spring 2007. Data collection should be complete by 2009. Data analysis will be carried out in parallel with and after data collection to the end of 2010. The main publication will be produced in 2009-2010.

Table 1. Project milestones.



8 Costs incurred by each research performing partner

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

	NINA	SINTEF	NERI	Univ Bristol	RSPB	NTNU	Totals
Personal and indirect costs	5 570						5 570
PhD student	1 776						1 776
Purchase of R & D services		1 000	463			200	1 663

Equipment	795						795
Operating costs	1 180		119	120	200		1 619
Totals	9 321	1 000	582	120	200	200	11 423

9 Financial contribution by partner

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

Year	Statkraft/EBL	NVE	Applied for to NFR
2007	408	204	2 447
2008	404	202	2 420
2009	351	176	2 099
2010	362	181	2 169
Totals	1 525	763	9 135

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

PART 2: Application of results

10 Relevance for knowledge-building areas

Wind power is generally agreed to be a broadly environmentally friendly type of energy. The project results will, it is hoped, contribute to improving the knowledge base on which this view is founded as they will give new information on specific vulnerabilities of bird species to wind turbine plants, and possible effects at the population level. Moreover, the project will significantly contribute to the assessment of cumulative effects on birds of the development of wind farms as a common feature along the Norwegian coastline. This will assist with improving the environmental friendliness of wind turbines by providing the data background for possible amelioration measures for turbines in place and for developing guidelines for future priorities regarding power plant siting which maximise environmental benefits while minimising adverse impacts.

11 Importance to Norwegian industry

a) The project will give important input to the wind power industry and the energy and environmental authorities to improve planning for future wind farms. The management authorities as well as the energy industry need information on possible environmental consequences of wind power development. There is also a need for qualitative improvement of standardised pre-construction studies. Such information is needed not only to reduce or avoid environmental conflicts, but also to develop mitigating measures at existing plants, and contribute to improved EIA processes.

b) A delay with respect to location and construction of wind turbines due to possible environmental conflicts could be an economic problem for the energy industry but also for the society

as a whole. Thus, an efficient process in identifying “yes” or “no” wind power plant areas could have a huge economic impact.

2 Relevance for call for proposals and programmes

One of the focuses of the RENERGI programme is renewable energy sources, like wind power, being explicitly mentioned in the announcement for the 2007 applications. Moreover, the announcement stresses the importance of research dealing with possible effects and environmental consequences of wind-power development.

13 Environmental impact The project results will give significant, increased knowledge about how wind power can affect birds adversely in coastal areas of Norway. It will particularly contribute to a better planning process, and give a tool for the pre-construction period to identify areas with high conflict potential. Potentially, it may also provide information usable for post-construction mitigating measures concerning ‘problem-turbines’.

14 Information and dissemination of results This is a project addressing issues with a significant level of conflict in Norway. Thus the information strategy will be based on 1) dialogue with the energy industry and information to the public locally, regionally and nationally, 2) annual progress reports and a final report from each research component (when the components represent a thematic, separate objective making it pertinent to do so), as well as an overall final report (in English with Norwegian summary), 3) scientific papers presenting the main results from the separate project components. The results will also be popularized in written media, including newspapers and magazines. The television and radio media will also be invited to cover the project and its results. Progress reports will be completed at the end of each fiscal year to be sent to institutions financing the project, and will be made available to the general public through the NINA web site. A larger, final report from the project will be distributed (in the same fashion) at the end of the project period. Progress reports will be written in English with Norwegian summaries. Results from the study will be presented at international conferences and submitted to international peer-review journals as these become available during the course of the project. We plan to publish results from each study, and also integrate results across disciplines where practicable. The project has a pronounced interdisciplinary and international approach, and we hope that our results and conclusions will be of interest to the applied scientific community within our disciplines, and be applicable in other European regions with similar environmental challenges.

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