
# FIRST YEAR POST-CONSTRUCTION MONITORING OF BATS AND BIRDS AT WIND TURBINE TEST CENTRE ØSTERILD

Scientific Report from DCE – Danish Centre for Environment and Energy No. 133 2015

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# Data sheet

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Abstract: The Department of Bioscience, Aarhus University was commissioned by the Danish Nature Agency to undertake a bat and bird monitoring programme of a national test centre for wind turbines near Østerild in Thy, Denmark. Here we present the results from the first year of the post-construction studies.
Bats were recorded in August, September and October 2013. A total of nine species were recorded. Species composition and occurrence were comparable to the results during summer and autumn 2011. Bats were recorded on 67-85% of survey nights at turbine sites and on every survey night at all ponds and lakes. High activities were recorded throughout the monitoring period at ponds and lakes. Overall, the bat activity level was higher in 2013 than in 2011 at ponds and lakes. Bat activity was higher near the wind turbines than at nearby forest edges. These differences suggest that bats exploit the food resources that accumulate on the turbine towers some nights. Whooper swan, taiga bean goose, pink-footed goose, common crane, light-bellied brent goose, white-tailed eagle and nightjar were included as focal species in the ornithological investigations. In addition, species specific data on all bird species occurring regularly in the study area were collected. On the basis of an intermediate assessment of collision risk, the potential impacts of the combined structures on the bird species occurring in the study area were considered unlikely to be significant. However, given the uncertainties in the assessment, the post-construction programme will continue to investigate potential impacts on bats and birds.

Keywords: Bats, birds, wind turbines, temporal activity pattern, flight altitude, collision risk, test centre, post-construction, impact assessment, Østerild, Denmark

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# Preface

In June 2010, the Danish Parliament passed a Public Works Act to establish a national test centre for wind turbines near Østerild in Thy, Denmark. This legislation requires that a bird, bat and vegetation monitoring programme should be implemented.

The Department of Bioscience at Aarhus University was commissioned by the Danish Nature Agency to undertake a monitoring programme of birds in the test area. The monitoring programme comprises one baseline (2011/12) and two post-construction study periods (2013/14 and 2015/16).

In 2012 we presented the results of the baseline monitoring programme, which was undertaken to establish a reference for the future analysis of the potential impacts on birds caused by the operation of the test centre and to provide a preliminary risk assessment for relevant species. Here we present the results of the first year of the post-construction monitoring programme for birds and bats, together with an assessment of the potential impacts of the test centre on the populations occurring in the study area.

The report is divided into two separate sections concerning bats and birds, respectively.


## Acknowledgements

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Morten Elmeros & Ole Roland Therkildsen

# Summary


## Bats

Bats were recorded at the National Test Centre for Large Wind Turbines and in its vicinity to assess the potential effects of the wind turbines and to study selected aspects of the potential conflicts between wind turbines and bat conservation interests.

Bats were detected using state-of-the-art bat ultra sound detectors to record the bats' echolocation calls. The surveys and studies were carried out during August, September and October 2013.

A total of nine species was recorded during the 2013 survey and studies: pond bat, Daubenton's bat, Nathusius' pipistrelle, soprano pipistrelle, serotine, parti-coloured bat, noctule, Leisler's bat and brown long-eared bat.

Pond bat, Daubenton's bat and Nathusius' pipistrelle were the most common species in the test centre area.

The overall species composition and occurrences of bats at the monitoring sites in the test centre area and its vicinity in 2013 were similar to the baseline survey in 2011.

Bat activity levels at the monitoring sites along forest roads in 2011 were similar to the levels recorded in 2013 at the wind turbine sites.

At the ponds in the test centre area and its vicinity the bat activity levels were significantly higher in 2013 than in 2011. The ponds are probably highly important as foraging sites for the local pond bat and Daubenton's bat populations throughout the summer and autumn.

Bat activity was higher around the wind turbine towers than along nearby forest edges and around the open-structured meteorological masts. These differences suggest that bats are attracted to the turbine towers. Most likely the bats forage on the large insect assemblies that some nights congregate on the turbine towers.

## Birds

In June 2010, the Danish Parliament passed a Public Works Act to establish a national test centre for wind turbines near Østerild in Thy, Denmark. This legislation requires that a bird, bat and vegetation monitoring programme should be implemented.

Since 2011, the technical facilities at the test centre have gradually been developed and various structures erected on site. The test centre comprises a total of seven test sites for wind turbines of up to a maximum height of 250 m. Each test site consists of a single wind turbine, each with a mast for meteorological measuring equipment (up to 150 m in height) located immediately to the west of each turbine. These masts are secured with guy-wires.

The test centre also comprises two masts supporting meteorological equipment at heights up to 250 m secured with guy-wires. These masts also support aviation safety lighting.

The Department of Bioscience at Aarhus University was commissioned by the Danish Nature Agency to undertake a monitoring programme of birds in the test area. The monitoring programme comprises one baseline (2011/12) and two post-construction study periods (2013/14 and 2015/16).

The test centre is located near several Special Protection Areas (SPAs), which are sites designated for their particular importance for birds. These SPAs have been classified for rare and vulnerable breeding birds (as listed on Annex I of the Directive) as well as for regularly occurring migratory species according to Article 4.2 of the EC Birds Directive and generally following the criteria for designation of wetlands of international importance. As a result of their high conservation interest the monitoring programme has focused on this group of species in both the baseline and post-construction studies.

In 2012 we presented the results from the baseline monitoring programme. On the basis of a preliminary assessment, we considered the potential impacts of the combined structures on the bird species occurring in the study area unlikely to be significant.

Here we present the results from the first year of the post-construction bird studies, which were carried out from August 2013 to October 2014, together with an intermediate assessment of the potential impacts of the test centre on the bird populations occurring in the study area.

The test centre has not yet been fully developed. Therefore this intermediate assessment was carried out on a total of four operational turbines in operation together with their associated structures, e.g. meteorological measurement and aviation safety lighting masts, which had all been established at the beginning of the study period.

Initially, whooper swan, taiga bean goose, pink-footed goose and common crane, were included in the baseline investigations. However, on the basis of the results obtained during the baseline studies, white-tailed eagle and light-bellied brent goose were also subsequently included as focal species in the post-construction programme.

Apart from minor modifications and special efforts targeted towards light-bellied brent goose and nightjar (see below), the design of the post-construction study was similar to the baseline study, which aimed at generating species-specific data, whenever this was technically possible. For this reason, although data was partly collated from comprehensive automated recording processes, the collection of high quality and high resolution data at the species level was given priority at all times in the investigations. We used visual transect counts, vertical radar and laser range finder data, which was combined to provide the basic information for the assessment. In addition, we conducted carcass searches using trained dogs under turbines and masts to quantify actual fatality rates.

In general, the post-construction study supported the conclusions from the baseline study. We confirmed that the test centre is not situated on a migration corridor, although seasonal migration took place to some extent, particularly during the night. During the day, flight activity in the study area was dominated by local birds moving between feeding areas and night roosts in northwest Jutland, some of which has been designated as SPAs for the species included in the study. As was the case during the baseline study, we demonstrated local movements to take place on a regular basis for a number of species.

From the results of the baseline study, the species for which we estimated that more than one annual collision with wind turbines would take place were cormorant (3 individuals per year), pink-footed goose (21-46), greylag goose (3-6) and golden plover (65).

Based on the post-construction study, we estimated that the annual collision rate with wind turbines that exceeded one would be for cormorant (6-14), pink-footed goose (10-23), greylag goose (23-52), buzzard (0.8-1.6), golden plover (3-7), wood pigeon (0.5-1.2) and passerines (3-5).

For all of these species, a high proportion of individuals passing the study area did so at rotor height. Nevertheless, this still only resulted in a relatively limited number of predicted collisions even for these species. It is also important to note that in contrast to the baseline study, the post-construction study period covered the whole annual cycle, except for June-July.

For the remainder of the species that regularly occur in the study area, including the focal species whooper swan, taiga bean goose, common crane, light-bellied brent goose and white-tailed eagle, we predicted that the annual number of collisions would be less than one. This was typically because, for these species, a high proportion of individuals and flocks migrating occurred at flight altitudes below the rotor height of the wind turbines.

Five territories of nightjars were registered on the basis of the spatially consistent presence of advertising males in July 2014. We were unable to estimate the collision risk between turbines and nightjars and therefore the assessment of potential adverse impacts on the local breeding population awaits further studies. This issue will therefore be addressed in the second post-construction study year.

On the basis of this intermediate assessment, which used more reliable estimates of collision risk than those obtained during the baseline study, we still consider the potential impacts of the combined structures on the bird species occurring in the study area unlikely to be significant. We stress that our crude estimates of the number of collisions should be interpreted with caution. We are therefore cautious when comparing the collision estimates between the two study periods.

Since the test centre had only four turbines in operation during the post-construction study period, the assessment do not consider a fully developed test centre, which may have up to seven turbines in operation. The presence of more turbines may affect flight behaviour and migration pathways, which may potentially affect the risk of collisions between birds and turbines and other structures. Therefore the calculated number of collisions must be regarded as a crude estimate, which means that the potential impact of the test centre on bird species may be somewhat underestimated. However, this does not affect the conclusion that the overall impact of the test centre on bird species is considered unlikely to be significant.

Although no bird corpses were retrieved during the carcass searches, we consider the apparent complete absence of collisions between birds and the structures at the test centre to be highly unlikely. We therefore assume that either some fatalities were not detected because their remains were not available or missed by the dogs or they were removed by scavengers between searches. Nevertheless, the results from the carcass searches indicate that the number of collisions is probably rather small. The results from the carcass searches therefore support our conclusion that although collisions between turbines and other structures at the test centre are to be expected, they will occur at a low rate.

It is important to keep in mind that the data collected during the baseline and the post-construction programmes only covers less than two years. We are therefore cautious when we assess the extent to which there may be year-to-year variation in the occurrence of birds both during night and day. In particular, different weather conditions can affect flight behaviour and migration pathways, which may affect the risk of collisions.

# Sammenfatning

## Flagermus

Forekomsten og aktiviteten af flagermus blev registreret i og omkring det nationale testcenter for store vindmøller for at overvåge og vurdere om vindmøllerne påvirker flagermusene i området og for at undersøge flagermus' adfærd ved vindmøller og potentielle konflikter med beskyttelsen af flagermus.

Flagermusene blev registreret med ultralydsdetektorer, der kan optage flagermusenes ekkolokationsskrig. Overvågningen og undersøgelserne af flagermusenes adfærd ved møller blev gennemført i løbet af august, september og oktober 2013.

Der blev registreret i alt ni flagermusarter under overvågningen og undersøgelserne i 2013: damflagermus, vandflagermus, troldflagermus, dværgflagermus, sydflagermus, skimmelflagermus, brunflagermus, Leislers flagermus og langøret flagermus.

Damflagermus, vandflagermus og troldflagermus var de almindeligste arter i testcentret.

Artssammensætningen og forekomsten af flagermus på overvågningsstederne i og omkring test centret svarede til resultaterne af baseline registreringen i 2011.

Aktiviteten af flagermus på overvågningsstederne langs skovveje i 2011 og ved møllepladserne i 2013 var på samme niveau.

Ved søer og damme i og omkring testcentret var flagermusaktiviteten signifikant højere i 2013 end i 2011. Søerne og dammene er formentlig vigtige fourageringssteder for de lokale bestande af damflagermus og vandflagermus gennem sommeren og efteråret.

Der var højere aktivitet af flagermus ved vindmølletårnene end langs nærliggende skovbryn og ved meteorologiske master. Disse forskelle i flagermusaktiviteten indiker, at vindmølletårnene har en attraktionsværdi for flagermusene, formentlig som fourageringssteder, fordi der på nogle aftner samler sig store mængder af insekter på mølletårnene.

## Fugle

I juni 2010 besluttede Folketinget at etablere et nationalt testcenter for vindmøller nær Østerild i Thy. Med beslutningen fulgte et krav om at gennemføre et overvågningsprogram for de potentielle effekter på fugle, flagermus og vegetation i området.

I 2011 blev den gradvise udbygning af de tekniske faciliteter i testcenteret påbegyndt. Der er plads til at teste op til syv vindmøller med en højde på op til 250 meter til øverste vingespids. Hver testplads består af en vindmølle med en tilknyttet målemast på op til 150 meters højde, der er placeret umiddelbart vest for møllen.

Testcenteret har desuden to målemaster på op til 250 meters højde, der er udstyret med lys af hensyn til flysikkerheden. Alle master er sikret med et antal barduner.

Institut for Bioscience, Aarhus Universitet, har af Naturstyrelsen fået til opgave at gennemføre overvågningen af fugle i området. Overvågningsprogrammet består af en baseline-undersøgelse (2011/12) samt to år med undersøgelser efter etableringen af testcenteret (2013/14 og 2015/16).

Testcenteret er placeret nær flere Fuglebeskyttelsesområder, der er udpeget på grund af deres betydning for fuglearter, der er opført på Fugleskyttelsesdirektivets Bilag I. Disse Fuglebeskyttelsesområder sikrer beskyttelse af sjældne og sårbare ynglefugle samt regelmæssigt forekommende trækfugle. Overvågningsprogrammet har derfor fokuseret på disse arter, der således er omfattet af internationale beskyttelsesinteresser.

I 2012 præsenterede vi resultaterne af baseline-undersøgelserne. På baggrund af en foreløbig vurdering konkluderede vi, at den potentielle negative effekt af etableringen af testcenteret på de berørte fuglebestande formentlig var begrænset.

I denne rapport præsenterer vi resultaterne af den første undersøgelse efter etableringen af testcenteret. Undersøgelsen blev gennemført i perioden fra august 2013 til oktober 2014. Vi fremlægger dermed den anden foreløbige vurdering af den potentielle negative effekt af etableringen af testcenteret på de relevante fuglebestande, herunder fugle, der yngler eller raster i området eller i de omkringliggende fuglebeskyttelsesområder, samt fugle på egentligt træk.

Testcenteret er endnu ikke fuldt udbygget. Denne vurdering tager derfor udgangspunkt i de fire møller, der er i drift, samt målemasterne, der alle var opført ved undersøgelsens påbegyndelse.

Sangsvane, skovsædgås, kortnæbbet gås og trane var oprindeligt udpeget som fokusarter og dermed omfattet af baseline-undersøgelsen. På baggrund af deres tilstedeværelse i studieområdet under baseline-undersøgelserne blev havørn og lysbuget knortegås desuden inkluderet som fokusarter i nærværende undersøgelse.

Bortset fra mindre justeringer og en særlig indsats rettet mod lysbuget knortegås og natravn (se nedenfor) svarede undersøgelsens design til baseline-undersøgelsen. Vi forsøgte således at indsamle artsspecifikke data i det omfang, det var teknisk muligt. Dataindsamlingen var derfor kun delvist automatiseret. I stedet blev det prioriteret at generere artsspecifikke data af høj kvalitet og opløsning. Vi kombinerede transekttællinger, vertikal radar og laserkikkert for at indsamle de data, der dannede grundlag for vurderingen. Vi gennemførte desuden afsøgninger med hunde under møller og master med henblik på at kvantificere omfanget af kollisioner.

Overordnet set bekræftede undersøgelserne efter etableringen af testcenteret resultaterne af baseline-undersøgelsen. Det blev således bekræftet, at testcenteret ikke er beliggende på en trækkorridor, selvom et egentligt sæsontræk fandt sted i et vist omfang, især om natten. Vi kunne desuden påvise, at flere arter regelmæssigt trækker mellem fourageringsområder og overnatningspladser i området.

På baggrund af baseline-undersøgelsen estimerede vi, at der ville forekomme mere end én kollision med vindmøller om året for følgende arter: Skarv (3), kortnæbbet gås, (21-46), grågås (3-6) og hjejle (65).

I nærværende undersøgelse estimerede vi, at der ville forekomme mere end én kollision med vindmøller om året for følgende arter: Skarv (6-14), kortnæbbet gås (10-23), grågås (23-52), musvåge (0,8-1,6), hjejle (3-7), ringdue (0,5-1,2) og småfugle (3-5).

Selvom disse arter alle er karakteriseret ved, at en relativt stor andel af individerne passerede området i rotorhøjde, resulterede dette i et forholdsvist begrænset antal estimerede kollisioner. Det skal i denne forbindelse bemærkes, at modsat baseline-undersøgelserne dækkede nærværende undersøgelse hele året bortset fra juni-juli.

For de resterende arter, der forekommer i området, inklusiv fokusarterne sangsvane, skovsædgås, trane, lysbuget knortegås og havørn, er det estimerede antal årlige kollisioner mindre end én. Dette skyldes typisk, at en stor andel af individerne eller flokkene tækker gennem området under vindmøllernes rotorhøjde.

I juli 2014 registrerede vi fem territoriehævdende natravne i studieområdet. Det er ikke muligt at estimere kollisionsrisikoen for natravn og en vurdering af de potentielle negative effekter på denne lokale ynglebestand er ikke mulig på baggrund af det nuværende datagrundlag. Denne problemstilling vil der være taget højde for i de videre undersøgelser.

Denne foreløbige vurdering af kollisionsrisici bygger på mere robuste estimater for antallet af kollisioner, end det var tilfældet i baseline-undersøgelserne. Vi vurderer derfor fortsat, at den potentielle negative påvirkning af fuglearter i området sandsynligvis er begrænset. Vi understreger dog, at antallet af forventede kollisioner fortsat er omfattet af en vis usikkerhed og dermed skal anvendes med forsigtighed. Vi er derfor forsigtige med at sammenligne kollisionsestimater fra de to undersøgelsesår, selvom den samme metode er anvendt i begge perioder.

Da testcenteret ikke var fuldt udbygget, mens undersøgelserne fandt sted, omfatter vurderingen ikke et testcenter med de maksimale syv møller i drift. Et øget antal møller kan påvirke fuglenes flyveadfærd og trækmønstre på både lille og stor skala. Dette kan potentielt påvirke risikoen for kollisioner med møller og master. Det estimerede antal kollisioner skal derfor betragtes som et forsigtigt skøn, der muligvis er for lavt. Dette ændrer dog ikke ved, at vi overordnet set vurderer, at påvirkningen af testcenteret på de berørte fuglebestande sandsynligvis er begrænset.

Under afsøgningerne med hunde blev der ikke fundet fugle, der var døde som følge af kollisioner med møller og master. Vi vurderer dog, at det er sandsynligt, at der sker kollisioner. Vi antager derfor, at enten lykkedes det ikke hundene at finde de døde fugle i forbindelse med afsøgningerne, eller også blev fuglene taget af ådselsædere mellem afsøgningerne. Ikke desto mindre indikerer resultatet af afsøgningerne, at antallet af kollisioner sandsynligvis er ret lavt. Afsøgningerne understøtter derfor vores vurdering, idet kollisioner må forventes at forekomme, men at disse har et begrænset omfang.

Det er vigtigt at bemærke, at baseline-undersøgelsen og undersøgelsen efter etableringen af testcenteret omfatter en periode på mindre end to år. Der kan således være år-til-år-variation i fx forekomsterne af fugle, både om dagen og om natten. Især kan forskelle i vejrforholdene påvirke flyveadfærd og trækmønstre på både lille og stor skala, hvilket igen kan påvirke risikoen for kollisioner.

# Part A:

# Bat studies at Wind Turbine Test Centre Østerild, 2013

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# Introduction

The national test centre for large wind turbines in Østerild was constructed in 2011. An environmental monitoring programme was established for the first years of operation to assess the potential effect of the wind turbines on local bat populations and to study selected aspects of the potential conflict between wind turbines and bat conservation interests.

Bat fatalities at wind turbines have been recognized as a major cause for concern for the conservation of bat populations in many of our neighbouring countries and in northern America (e.g. Brinkmann et al. 2006, Hötker 2006, Ahlén et al. 2007, Kunz et al. 2007, Arnett et al. 2008, Rodrigues et al. 2008). Observations of bats near wind turbines show that bats approach and investigate various parts of the turbine repeatedly (Horn et al. 2008). The bats have been observed to follow or become trapped in the air vortices behind the turbine blades.

Bats are killed either by direct collisions by the rotating turbine wings or by barotrauma caused by the rapid changes in air pressure created around a turbine wing as it is moving through the air (Baerwald et al. 2008, Grodsky et al. 2011, Rollins et al. 2012). The number of fatalities at wind turbines is affected by the geographic location, habitat characteristics of the site, turbine height and wind speed (Ahlén 2010, Hötker 2006, Barclay et al. 2007, Arnett et al. 2008, Dulac 2008, Baerwald & Barcley 2009, Baerwald et al. 2009).

There is a positive correlation between the numbers of bats and insects observed flying near wind turbines (Horn et al. 2008). The accumulation of insects on the wind turbine structures may attract the bats (Ahlén et al. 2007, Rydell et al. 2010). Some bat species may also use the wind turbines as roost sites (Ahlén et al. 2007). Bats have previously been recorded at nacelle height, i.e. at higher altitudes than normally recorded. Presumably, the bats forage on insects up along the turbine tower and/or examine the structure looking for potential roost sites.

The life-history traits of all bat species (long life expectancy, low fecundity and reproductive rate) render their populations very susceptible to increased mortalities (Kunz & Fenton 2003). Population models suggest that the increased mortality caused by 1000 wind turbines in Sweden may result in 20-30% declines in the population sizes of noctule (*Nyctalus noctula*) and Nathusius' pipistrelles (*Pipistrellus nathusii*) over the next 30 years in Sweden (Rydell et al. 2011). These significant reductions in population sizes result from annual mortalities of 0.9 noctules and 0.7 Nathusius' pipistrelles per turbine, which are the average numbers found in surveys in Germany (Seiche 2008, Dürr 2009). In Denmark, there are now more than 4,500 land-based wind turbines and 500 offshore wind turbines in operation (www.ens.dk).

Bats were monitored in the test centre area and its vicinity prior to and during the early construction phase in the late summer and autumn of 2011 as a baseline. During the baseline survey in Østerild in 2011, seven bat species were recorded in the test centre area (Elmeros et al. 2012). Pond bat (*Myotis dasycneme*), Daubenton's bat (*Myotis daubentonii*) and Nathusius' pipistrelle were the most common species recorded throughout the survey area and period. Serotine bat (*Eptesicus serotinus*), soprano pipistrelle (*Pipistrellus pyg-*

*maeus*), parti-coloured bat (*Vespertilio murinus*) and brown long-eared bat (*Plecotus auritus*) were recorded more sporadically. Previous bat surveys had recorded the same species in Thy (Møller et al. 2013).

The national conservation status and the red-list population status of the recorded bats are shown in Table 1. The status was assessed from the national distribution and occurrence at a limited number of monitoring sites. No systematic data are available on the national or local population size and development.

**Table 1.** List of the bat species recorded in Thy previously and during the 2013 monitoring programme, the species' overall conservation status in the Atlantic biogeographic region in Denmark following the Habitat Directive Article 17 assessment (European Commission 1992, Søgaard et al. 2008), and the national red list assessment (Elmeros et al. 2010). Fav.: favourable, Unfav-1: Moderately unfavourable, LC: Least concern, VU: Vulnerable). The Leisler's bat is a rare migrant in Denmark. Previously it has been recorded sporadically in southern Denmark (Møller et al. 2013).

| | | | | Habitat directive | | |
|---|---|---|---|---|---|---|
| **Abbreviation** | **English name** | **Danish name** | **Latin name** | **Annex** | **Conservation status** | **National Red list** |
| *Mdas* | Pond bat | Damflagermus | *Myotis dasycneme* | II & IV | Fav. | VU |
| *Mdau* | Daubenton's bat | Vandflagermus | *Myotis daubentonii* | IV | Fav. | LC |
| *Pnat* | Nathusius' pipistrelle | Troldflagermus | *Pipistrellus nathusii* | IV | Fav. | LC |
| *Ppyg* | Soprano pipistrelle | Dværgflagermus | *Pipistrellus pygmeaus* | IV | Unfav-1 | LC |
| *Nlei* | Leisler's bat | Leisler's flagermus | *Nyctalus leisleri* | IV | n/a | n/a |
| *Nnoc* | Noctule | Brunflagermus | *Nyctalus noctula* | IV | Fav. | LC |
| *Eser* | Serotine | Sydflagermus | *Eptesicus serotinus* | IV | Fav. | LC |
| *Vmur* | Parti-coloured bat | Skimmelflagermus | *Vespertilio murinus* | IV | n/a | LC |
| *Paur* | Brown long-eared bat | Langøret flagermus | *Plecotus auritus* | IV | Fav. | LC |

In 2013, the monitoring programme at Østerild included monitoring of bat occurrence and species composition for comparison with the baseline study from 2011, recordings of bat activity at different distances from the wind turbines and at nacelle height, observations of bats' flight behaviour with thermography camera around the turbine tower and searches for bat carcasses to estimate fatality rates. During the baseline survey in 2011, the occurrence and activity of bats were highest in the southern most turbine sites situated in forest (Elmeros et al. 2012). Hence, the studies on bat behaviour near wind turbines were concentrated on the wind turbines at site 6 and 7 in late summer and autumn in 2013 (Figure 1 and 2).

**Figure 1.** Bat monitoring sites in the national test centre area in Østerild Plantation and its the vicinity (Wind turbine sites: red, Ponds: blue).

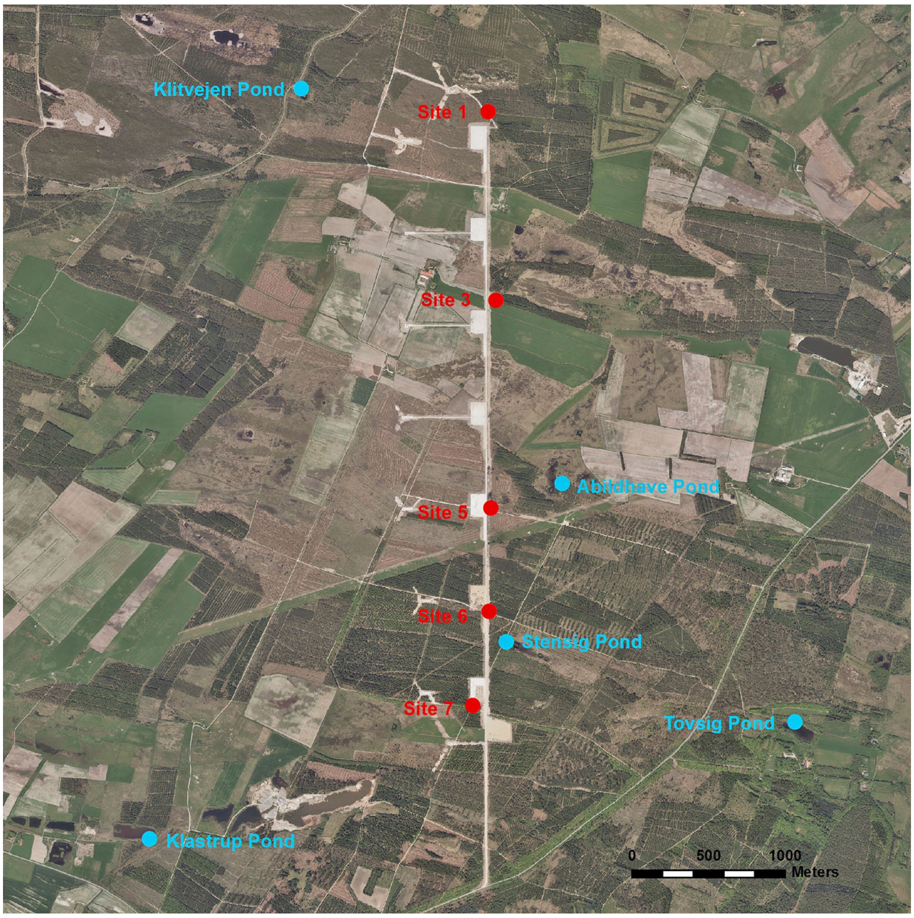


**Figure 2.** Monitoring sites for the study of bat activity in relation to distance to wind turbine towers and meteorological mast.

# Materials and methods

## Detectors and species identification

Bats were detected using state-of-the-art bat detectors with capacity to record real-time, full-spectrum recordings of the bats' echolocation calls.

Occurrence and activity levels of bats in the test centre area and nearby ponds and at different distances from the turbine towers were recorded with automatic Pettersson D500X-detectors (Pettersson Electronik AB). Manual monitoring and direct observation of bat behaviour and use of the test centre area was achieved using primarily Pettersson D1000X ultrasound detectors and secondarily Pettersson D240X detectors coupled to an Edirol R09HD recorder. Recordings of bat calls were stored and archived as uncompressed wav-files.

Bat activity at nacelle heights was monitored with a Batcorder 3.0 detector coupled with a specially designed wind turbine extension kit and microphone from EcoObs GmbH. Recordings with this detector were stored as raw audio files and converted to wav-files for analysis.

Recordings of bat calls were analysed using BatSound 4.01 (Pettersson Elektronik AB) to identify species. Species were identified based on the characteristics of their echolocation calls: frequency band, frequency of maximum energy, duration of the calls and intervals between calls.

Bats show considerable plasticity in their calls depending on their behaviour. Bats in the *Myotis* genus (e.g. pond bat, Daubenton's bat, Brandt's bat and Natterer's bat that all occur in Jutland) have very similar echolocation calls. Many *Myotis* calls cannot be identified to species level, and visual observations of the bats and their flight pattern together with the calls are often needed to differentiate *Myotis* species. The pond bat is usually identifiable. At some nights we attempted to identify all recorded *Myotis* calls to assess the relative proportion of pond bats among the *Myotis*-bats recorded at the survey sites during the surveys. Also noctule (*Nyctalus noctula*), Leisler's bats (*Nyctalus leisleri*), serotine and part-coloured bats are problematic to identify from their calls in certain situations, e.g. when approaching and investigating structures or catching an insect.

The bat calls are detectable at distances from 5 to 100 m depending on species and the type and direction of the call that the bats are emitting. Generally, the more commonly detected bat species at Østerild were detected at 15-30 m. Echolocation calls from brown long-eared bat can only be detected from short distances <10m, while some calls from high-flying noctules sometimes are detected at distances up to 100 m.

For further information of monitoring methods and species identification from their echolocation calls, see Ahlén & Baagøe (1999), Baagøe & Ahlén (2001) and Søgaard & Baagøe (2012).

## Monitoring of bat occurrence and activity levels

Bats were monitored at five wind turbine sites, at two ponds inside the test centre area and at three ponds in the vicinity of the test centre area with automatic detectors for up to 12 nights from early August to late October 2013 (Table 2, Figure 1). The same sites, lakes and ponds were monitored during the baseline survey in 2011 (Elmeros et al. 2012).

**Table 2.** Nights per month when bat activity was recorded at wind turbine site and ponds in the test centre area and its vicinity in 2013.

| Location | August | September | October |
|---|---|---|---|
| Site 1 | 3 | 4 | 5 |
| Site 3 | 4 | 4 | 5 |
| Site 5 | 3 | 4 | 5 |
| Site 6 | 4 | 4 | 4 |
| Site 7 | 3 | 3 | 5 |
| Klastrup Pond | 3 | 3 | 5 |
| Stensig Pond | 3 | 4 | 5 |
| Klitvejen Pond | 1 | | 1 |
| Abildhave Pond | 3 | 4 | 5 |
| Tovsig Pond | | | 3 |

During the baseline survey of bats in 2011, detectors were placed along forest roads and forest edges near the projected wind turbine sites. Habitat changes, e.g. forest clearing, may affect bat activity at a fine spatial scale. To avoid biases in the 2013 survey due to habitat changes at sites where the forest had been cleared, the detectors in 2013 were placed along forest edges at the same location as in the baseline survey or in forest edges facing the wind turbine sites near the original location.

Bat activity at ponds in the test centre area and the vicinity was monitored to determine species occurrence in eastern Thy and activity levels at potential major foraging sites. The survey at sites outside the test centre area may also serve as a reference for assessments of potential effects of habitat changes or operation of wind turbines in the test centre area. The bat activity and behaviour was observed directly for 20-30 minutes to assess number of individuals that may occur simultaneously at the ponds (assesses to the categories: 1, 2-5, 6-15 and >15) (Søgaard & Baagøe 2012).

## Bats near turbine towers

Assuming that bats are 'attracted' to the towers or tend to forage more near the turbine towers, we would expect a higher activity level near the turbines than at the nearby monitoring sites along forest edges. The bat activity at different distances near the two southern wind turbines (Site 6 and 7) and the meteorological mast west of Site 7 were recorded for four nights. At Site 7, two additional nights were included.

Automatic bat detectors (Pettersson D500X) were placed next to the turbine tower (at the lee side of the tower), in the forest edge towards the open wind turbine site (ca. 50 m from the turbine), and in the forest edge 100 m and 150 m from the turbine towers.

A set of bat detectors were placed in the forest clearing 0 m, 50 m and 150 m from the meteorological mast in the forest edge towards the meadow between the forest and the southern light mast.

## Bats at nacelle height

Automatic bat detectors were installed in the nacelle of the wind turbines at Site 6 and 7 to record activity of bats near the upper part of the turbine tower and under the nacelles. The microphone for the detectors protruded through the underside of the nacelle just behind the tower relative to the rotor. These bat detectors were in operation from early September to early November.

## Thermographic observations

We employed a thermography camera (FLIR A320 Industrial Automation IR Camera) to observe bats' flight patterns near the operating wind turbine at Site 7. The recording sessions were started at dusk and continued until four hours after sunset on the 7th and 15th October 2013. The camera was positioned ca. 30 m from the base of the tower. The camera's view ranged from ca. 5 m to 30 m above ground.

The FLIR A320 thermography camera has a 320 x 240-pixel sensor and captures images at a rate of minimum 3-5 frames per second and stamped each data frame with time. The temperature range is -25° to 120° C, but during data processing of the images, the temperature sensitivity was set to 0° - 25° C. The images were streamed and stored real-time to a laptop computer. We monitored the recording real-time at the computer and later manual playback of the images.

To identify the species of bats observed with the IR camera, the bat activity was recorded simultaneously using an automatic bat detector (Pettersson D500X) placed at the base of the tower. Detectors were also monitored at four sites (2 x 50 m and 2 x 100 m) along forest edges around the wind turbine site to monitor the general bat activity level at the site. These recordings are included in the assessment of bat activity at different distances to the tower.

## Bat carcasses search

For methodology and monitoring schedule - see description of carcasses search in the chapters on the bird monitoring programme in this report.

## Statistical analysis

For comparisons of bat activity levels between monitoring sites in 2011 and 2013, and activity levels at different distances to the wind turbine the bat activity was estimated as calls per hour. As bat activity is highest after sunset, only the activity during the first 4 hours of the night was estimated.

Negative binomial regression analyses were used to compare bat activity levels between years, site type (wind turbine and ponds), and bat activity levels at different distances to the wind turbine and site type (wind turbine and meteorological mast). Differences between years, site types and distances were compares by z-tests of the differences between least square mean estimates. The statistical analyses were performed using SAS 9.2 and SAS Enterprise Guide 4.1 (SAS Institute Inc., Cary, USA).

## Quality assurance and data storage

The detection and species identification methods used in this study correspond to the methods and high quality criteria that were defined in the national monitoring programme for bats (Søgaard & Baagøe 2012). Species identification of recordings was determined independently by a minimum of two observers, if calls were not characteristic and easily identifiable. All recordings are stored electronically as uncompressed audio files (wav- or raw-format) at Department of Bioscience, AU.

# Results & discussion

## Occurrence of bat species

The overall species composition, spatial occurrence and activity levels of the different bat species were similar to those recorded in the 2011-baseline survey (Table 3, 4 and 5). The most commonly recorded species were pond bats, Daubenton's bats and Nathusius' pipistrelle at all monitoring sites. On some nights all the *Myotis*-bat recorded at wind turbines sites were pond bats. At the ponds up to 80% of the recorded *Myotis*-bat calls were pond bats. Thus, pond bats are regularly foraging over the ponds inside and in the vicinity of the test centre area and commuting thorugh the forest past the wind turbine sites. As in 2011, soprano bat, serotine and parti-coloured bat were recorded irregularly in 2013.

**Table 3.** Frequency of occurrence (% of monitored nights) of bats recorded up to four hours after sunset recorded with automatic detectors at turbine sites and ponds in the in the test centre area and its vicinity in 2013. See Figure 1 for locations and Table 1 for species abbreviations.

| | Any bat | *Myotis* | *Mdas* | *Pnat* | *Ppyg* | *Eser* | *Nnoc* | *Vmur* | *Paur* | Unidentified |
|---|---|---|---|---|---|---|---|---|---|---|
| Site 1 | 67 | 67 | 50 | 8 | 0 | 8 | 0 | 8 | 0 | 17 |
| Site 3 | 85 | 85 | 38 | 54 | 8 | 23 | 15 | 23 | 0 | 0 |
| Site 5 | 67 | 42 | 33 | 50 | 0 | 0 | 0 | 25 | 8 | 17 |
| Site 6 | 83 | 75 | 50 | 75 | 0 | 17 | 8 | 0 | 0 | 8 |
| Site 7 | 73 | 36 | 27 | 55 | 0 | 0 | 0 | 9 | 9 | 0 |
| Abildhave Pond | 100 | 100 | 92 | 92 | 0 | 0 | 0 | 25 | 0 | 17 |
| Klastrup Pond | 100 | 91 | 91 | 100 | 0 | 45 | 9 | 9 | 0 | 9 |
| Stensig Pond | 100 | 92 | 92 | 83 | 8 | 17 | 8 | 42 | 0 | 17 |
| Klitvejen Pond | 100 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tovsig Pond | 100 | 67 | 33 | 100 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 4.** Mean (and maximum) number of bat calls pr. hour recorded up to 4 hours after sunset recorded with automatic detectors at turbine sites and ponds in the test centre area and at ponds in the vicinity in Østerild Plantation in 2013. See Figure 1 for locations and Table 1 for species abbreviations.

| Location | *Myotis* | *Pnat* | *Ppyg* | *Eser* | *Nnoc* | *Vmur* | *Paur* | Unidentified |
|---|---|---|---|---|---|---|---|---|
| Site 1 | 0.26 (0.75) | 0.02 (0.30) | - | 0.02 (0.25) | - | 0.06 (0.76) | - | 0.05 (0.30) |
| Site 3 | 0.46 (1.75) | 0.14 (0.33) | 0.03 (0.33) | 0.11 (0.98) | 0.08 (0.75) | 0.16 (1.50) | - | - |
| Site 5 | 0.23 (1.00) | 0.15 (0.50) | - | - | - | 0.15 (1.00) | 0.02 (0.25) | 0.08 (0.75) |
| Site 6 | 0.29 (0.63) | 0.51 (2.00) | - | 0.05 (0.31) | 0.25 (3.00) | - | - | 0.06 (0.75) |
| Site 7 | 0.18 (1.00) | 0.54 (2.00) | - | - | - | 0.02 (0.25) | 0.02 (0.25) | - |
| Abildhave Pond | 28.58 (93.50) | 9.05 (62.32) | - | - | - | 0.21 (1.00) | - | 0.10 (1.00) |
| Klastrup Pond | 63.92 (176.78) | 4.57 (13.50) | - | 0.32 (1.25) | 0.11 (1.25) | 0.07 (0.75) | - | 0.09 (0.75) |
| Stensig Pond | 60.95 (185.75) | 7.73 (21.50) | 0.02 (0.25) | 0.88 (9.50) | 0.04 (0.50) | 0.30 (1.05) | - | 0.04 (0.25) |
| Klitvejen Pond | 19.00 (30.50) | - | - | - | - | - | - | - |
| Tovsig Pond | 5.67 (16.75) | 1.17 (1.75) | - | - | - | - | - | - |

**Table 5.** Frequency of occurrence (% of monitored nights) of any bats recorded up to four hours after sunset recorded with automatic detectors at forest roads / wind turbine sites and ponds in Østerild.

| | 2011 | | 2013 | |
|---|---|---|---|---|
| | **N** | **Any bat** | **N** | **Any bat** |
| Site 1 | 16 | 57 | 12 | 67 |
| Site 3 | 16 | 79 | 13 | 85 |
| Site 5 | 16 | 71 | 12 | 67 |
| Site 6 | 16 | 88 | 12 | 83 |
| Site 7 | 16 | 80 | 11 | 73 |
| Abildhave Pond | 10 | 100 | 12 | 100 |
| Klastrup Pond | 9 | 89 | 10 | 100 |
| Stensig Pond | 10 | 100 | 12 | 100 |
| Klitvejen Pond | 8 | 67 | 2 | 100 |
| Tovsig Pond | 2 | 100 | 3 | 100 |

Three new bat species were recorded in the test centre area in 2013. The brown long-eared bat that was recorded along forest edges at two wind turbine sites and at one of the turbines. It had previously only been recorded along Gl. Aalborgvej south of the test centre area (Elmeros et al. 2012, Baagøe pers. comm.). Two new species (noctule and Leisler's bat) were also heard in the study area in 2013.  The noctules and Leisler's bats have not been recorded previously in Thy (Møller et al. 2013). Noctules were recorded on different nights during the automatic monitoring, the manual monitoring at the ponds and during the study of bat activity at different distances to the turbines. The Leisler's bat was only recorded once during the study of activity at different distances to the turbines. Both species are long distance seasonal migratory species (Steffens et al. 2004), and vagrant individuals are often found outside their usual breeding range in late summer before the migration period.

The parti-coloured bat was recorded more regularly in 2013 than in 2011. This parallels the 2012-2013 results from the national monitoring programme (NOVANA) of bats, where the species has been recorded regularly at survey sites in western Jutland (Elmeros et al. unpublished).

## Activity levels of bats

Bat activity levels at the wind turbine monitoring sites were low compared to the activity levels recorded at lakes and ponds (Table 4). High foraging activity levels of pond bats and Daubenton's bats were recorded at lakes and ponds inside and in the vicinity of the test centre area. Buzzes – i.e. rapidly repeated calls emitted when the bats are closing in to catch an insect – of pond bats, Daubenton's bats and Nathusius' pipistrelles were regularly recorded at the pond sites.

More than five individual pond bats were observed simultaneously foraging over Klastrup Pond during manual monitoring. Two and three individual *Myotis*-bats were also registered on many of the recordings from the automatic bat detector. Usually, 1-2 individuals of pond bats and Daubenton's bats were observed foraging at the ponds.

Pond bat, Daubenton's bat and Nathusius' bats were observed at the ponds shortly after sunset on several nights. The individual bat optimizes its energy gain by visiting several suitable foraging habitats sites, first visiting feeding habitats where they expect to find the most profitable food resources following ideal free distribution theory (Dietz et al. 2006, Encarnação et al. 2010). The early arrival of *Myotis*-bats at the ponds in the test centre area could suggest that the bats commute directly to the ponds in the test centre area to forage soon after emerging from their roosts in the evening. There are no suitable roosting sites in the coniferous forest in the test centre area. Known roost sites for pond bats and Nathusius' pipistrelle are found more than 2 km from the test centre area in buildings in Tovsig and Østerild.

The temporal variation in activity levels of *Myotis*-bats and Nathusius' pipistrelle at forest roads/turbine sites and ponds in 2011 and 2013 is shown in Figure 3. At the monitoring sites in the test centre area similar levels of bat activity were recorded in 2013 and 2011 (Table 6). Bat activity was relatively constant at the forest roads/wind turbine sites in August, September and October in both 2011 and 2013.

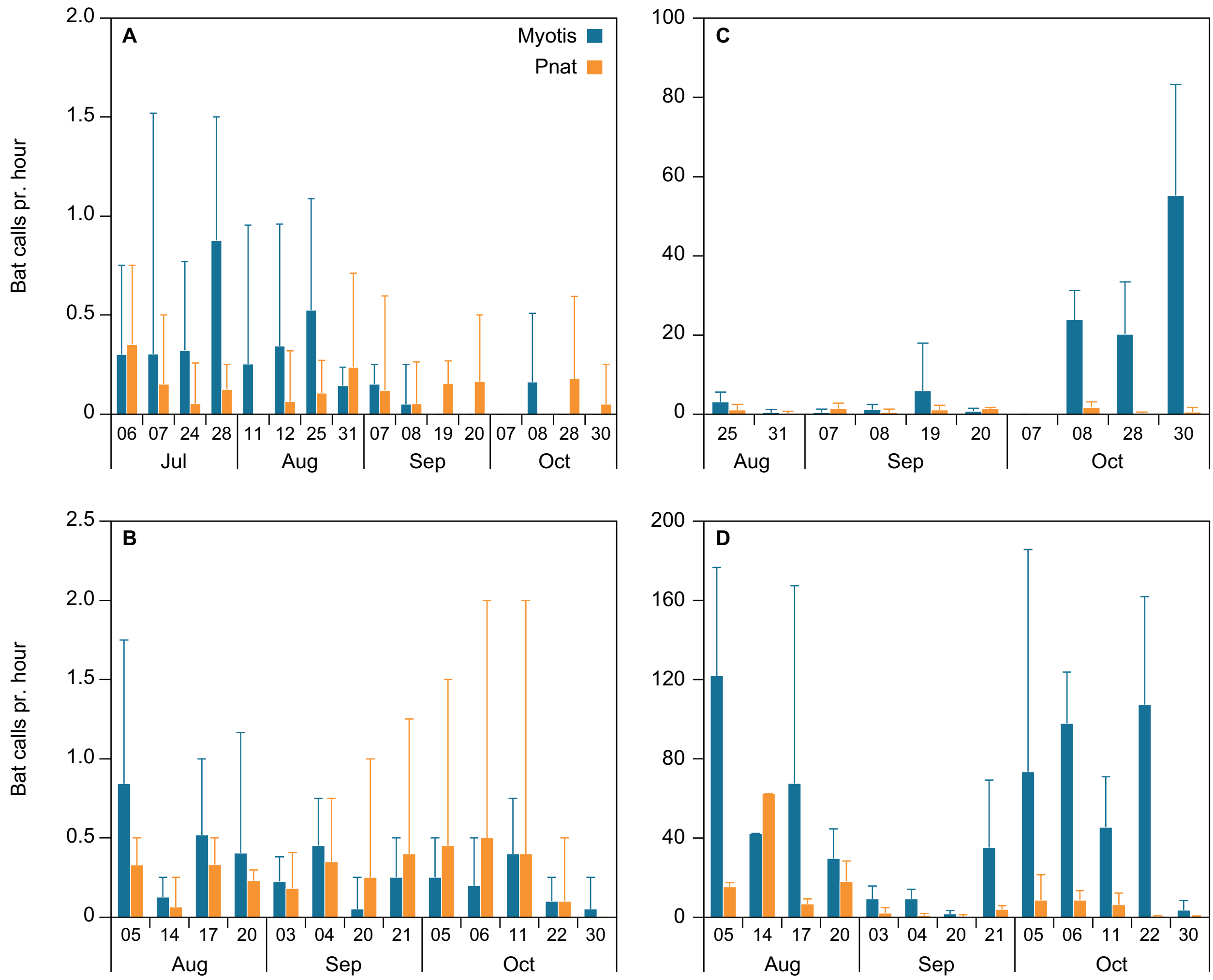


**Figure 3.** Temporal variation in bat activity (mean and max calls pr. hour) during the first 4 hours after sunset recorded with automatic detectors at forest roads in 2011 (A) and turbine Sites in 2013 (B) and at ponds (Abildhave Pond, Stensig Pond and Klastrup Lake) in 2011 (C) and 2013 (D). *Myotis*: Pond bats and Daubenton's bats. Pnat: Nathusius' pipistrelle.

**Table 6.** Differences of monthly bat activity (calls pr. hour) at different types of monitoring sites (forest roads, turbine Sites and ponds) in Østerild Plantation in August-October 2011 and 2013. Bold numbers in the last column indicate significant differences between years.

| Type & year | | | Month | LS Mean difference | z value | P |
|---|---|---|---|---|---|---|
| Forest roads, 2011 | x | Turbine sites, 2013 | Aug | -0.770 | -1.45 | 0.148 |
| | | | Sep | -1.717 | -2.65 | **0.008** |
| | | | Oct | -1.183 | -1.55 | 0.121 |
| Ponds, 2011 | x | Ponds, 2013 | Aug | -2.211 | -4.19 | **<.001** |
| | | | Sep | -1.805 | -4.11 | **<.001** |
| | | | Oct | -0.977 | -2.77 | **0.006** |

At the ponds, bat activity was dominated by *Myotis*-species (pond bats and Daubenton's bats) in both years, but activity levels were significantly higher in 2013 than in 2011 (Figure 3, Table 6). The temporal variation in activity levels were very high both years and differed between years. In 2011, the bat activity was relatively low in August and September and increased in October in 2011. In 2013, high levels of activity of *Myotis*-bats were recorded in all three months.

The bat surveys in the test centre area in 2011 and 2013 suggest that there have been no negative effects on the occurrence of bats in the wind turbine centre area after the first year of operation.

The high activity levels of bats at the small ponds in the plantation in and near the test centre show that the ponds represent highly important foraging sites for the local bat populations throughout the summer and autumn period. It must be assumed that the ponds are also important foraging sites for the bats in the spring and early summer.

Developing more wetlands near the wind turbines in the test centre area as described in the implementation plan for the test centre area will inevitably increase the activity levels of bats in the test centre area and hence, increase the probability that an individual bat will forage near the turbines increasing the risk for bat fatalities.

## Bat activity near turbine tower

*Myotis*-species and Nathusius' pipistrelle were the most common species recorded in the study of bat activity at different distances to the wind turbine towers and the meteorological mast as in the monitoring of the overall occurrence and activity of bats in the test centre area (Table 8). Some nights all of the *Myotis*-bats recorded at the towers were pond bats.

The average bat activity levels recorded around the towers and nearby forest edges were comparable to the levels recorded along forest edges during monitoring, but low compared to the bat activity recorded at the monitoring sites at the ponds. Most recordings of bats near the turbines and along the forest edges in the test centre areas were commuting past the monitoring sites. However, the activity level fluctuated and on some nights high levels of bat activity were recorded around the towers. Buzzes of Nathusius' pipistrelles were recorded near the turbine towers and two individuals were observed foraging simultaneously near the wind turbine tower.

**Table 7.** Differences of recorded activity (calls pr. hour) of *Myotis*-species and Nathusius' pipistrelle at monitoring sites in Østerild Plantation in August-October 2011 and 2013. *Low sample sizes of the ponds at Klitvejen and Tovsig. Bold numbers in the last column indicate significant differences between years.

| | Location | | LS Mean difference | z-value | P |
|---|---|---|---|---|---|
| *Myotis* species | Site 1 | 2011 x 2013 | -2.004 | -1.26 | 0.207 |
| | Site 3 | 2011 x 2013 | -0.949 | -1.09 | 0.277 |
| | Site 5 | 2011 x 2013 | -0.711 | -0.65 | 0.517 |
| | Site 6 | 2011 x 2013 | -0.783 | -0.80 | 0.425 |
| | Site 7 | 2011 x 2013 | 1.054 | 1.15 | 0.249 |
| | Abildhave Pond | 2011 x 2013 | -0.666 | -1.29 | 0.196 |
| | Klastrup Pond | 2011 x 2013 | -2.692 | -4.81 | **<.001** |
| | Klitvejen Pond* | 2011 x 2013 | -4.177 | -3.44 | **<.001** |
| | Stensig Pond | 2011 x 2013 | -1.059 | -2.00 | **0.046** |
| | Tovsig Pond* | 2011 x 2013 | 0.981 | 0.90 | 0.368 |
| Nathusius' pipistrelle | Site 1 | 2011 x 2013 | 0.362 | 0.15 | 0.877 |
| | Site 3 | 2011 x 2013 | -0.987 | -0.70 | 0.486 |
| | Site 5 | 2011 x 2013 | -0.283 | -0.24 | 0.807 |
| | Site 6 | 2011 x 2013 | -1.224 | -1.44 | 0.149 |
| | Site 7 | 2011 x 2013 | -0.857 | -1.10 | 0.271 |
| | Abildhave Pond | 2011 x 2013 | -1.952 | -3.72 | **<.001** |
| | Klastrup Pond | 2011 x 2013 | -2.481 | -3.36 | **<.001** |
| | Klitvejen Pond* | 2011 x 2013 | 20.810 | 0.00 | 0.999 |
| | Stensig Pond | 2011 x 2013 | -1.971 | -3.49 | **<.001** |
| | Tovsig Pond* | 2011 x 2013 | -0.614 | -0.45 | 0.652 |

**Table 8.** Mean (and maximum) number of bat calls pr. hour the first 4 hours after sunset recorded with automatic detectors at different distances from wind turbines and a meteorological mast in Autumn 2013. See Figure 1 for locations and Appendix 1 for species abbreviations.

| | Distance | N | Any bat | *Myotis* | *Pnat* | *Eser* | *Nlei* | *Nnoc* | *Vmur* | *Paur* |
|---|---|---|---|---|---|---|---|---|---|---|
| Met.mast 7 | 0 m | 4 | 1.14 (2.86) | 0.14 (0.57) | 0.91 (2.29) | - | - | - | 0.08 (0.33) | - |
| | 50 m | 3 | 1.31 (1.82) | 0.36 (1.09) | 0.84 (1.78) | - | - | - | 0.11 (0.33) | - |
| | 150 m | 2 | 6.03 (6.41) | - | 0.67 (0.75) | 5.37 (5.38) | - | - | - | - |
| Turbine 7 | 0 m | 6 | 1.69 (2.94) | 0.38 (1.10) | 1.25 (2.94) | - | - | - | - | 0.06 (0.37) |
| | 50 m | 8 | 0.88 (1.71) | 0.25 (1.07) | 0.59 (1.71) | 0.04 (0.34) | - | - | - | - |
| | 100 m | 4 | 1.83 (4.00) | 0.93 (2.40) | 0.90 (1.60) | - | - | - | - | - |
| | 150 m | 4 | 1.11 (1.79) | 0.18 (0.71) | 0.93 (1.40) | - | - | - | - | - |
| Turbine 6 | 0 m | 4 | 7.64 (21.19) | 0.41 (0.71) | 7.23 (20.90) | - | - | - | - | - |
| | 50 m | 4 | 1.06 (2.18) | 0.25 (0.65) | 0.81 (2.18) | - | - | - | - | - |
| | 150 m | 4 | 2.39 (6.53) | 0.24 (0.58) | 1.81 (6.53) | - | 0.08 (0.34) | 0.16 (0.68) | - | 0.09 (0.36) |

The bat activity was higher at the turbine towers than at forest edges near the wind turbine (Table 9, Figure 4). The bat activity level at the turbine towers was significantly higher than at 50 m, and tended to be higher than at 150 m from the turbine towers. Comparison of recorded bat activity level at the turbine towers and the open-structure meteorological masts suggests that the bat activity was elevated near the turbine towers (Table 9).

**Table 9.** Differences of least square mean estimates (LS Mean) of bat activity (calls pr. hour) the first 4 hours after sunset at (A) different distances from wind turbines and (B) at different distances between turbines and meteorological mast (B).

**A/**

| Distances | | | LS Mean difference | z value | P |
|---|---|---|---|---|---|
| 0 m | x | 50 m | 1.464 | 3.20 | 0.001 |
| 0 m | x | 100 m | 0.800 | 1.36 | 0.173 |
| 0 m | x | 150 m | 0.846 | 1.83 | 0.068 |
| 50 m | x | 100 m | -0.663 | -1.05 | 0.295 |
| 50 m | x | 150 m | -0.618 | -1.19 | 0.234 |
| 100 m | x | 150 m | 0.046 | 0.07 | 0.943 |

**B/**

| Distance | Site types | LS Mean difference | z value | P |
|---|---|---|---|---|
| 0 m | Turbine x Met. mast | 1.275 | -2.05 | 0.041 |
| 50 m | Turbine x Met. mast | 0.329 | 0.46 | 0.646 |
| 150 m | Turbine x Met. mast | -1.240 | 1.94 | 0.053 |

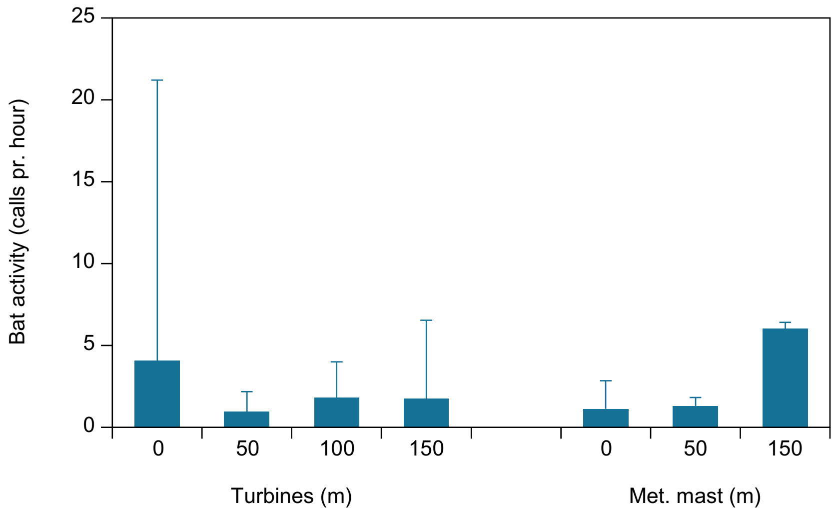


**Figure 4.** Bat activity (mean and maximum calls pr. hour) during the first 4 hours after sunset at different distances from wind turbine towers and a meteorological.

The sample size (number of monitored nights and replication of wind turbine towers and masts) was low and variation between nights was high. At two nights there was very high Nathusius' pipistrelle activity around one of the towers, and on two other nights high serotine activity was recorded at the monitoring site 150 m from the meteorological mast. Despite the limited sample size, these results suggest that bats spend time investigating and foraging around wind turbine towers.

Large numbers of insects were observed on the turbine tower after sunset on some nights. Most of the observed insects were lacewings (*Chrysopidae* sp.).

Groups of insects could be observed up to at least 15 m. The numbers of insects on the turbine towers showed large variations between nights.

## Bat activity at nacelle height

The detectors in the wind turbines at Site 6 and 7 have made 180 and 26 recordings in September and October. The number of recordings made in one night was 23. None of these recordings had been triggered by bats. The detectors had probably been triggered by noise from the turbine.

## Thermography camera

No bats were observed foraging around the turbine towers during the two evenings where the tower was monitored with a thermography camera. Bat detectors deployed in the forest edges around wind turbine site and the tower showed that the activity level of bats was relatively low on the two nights with thermography camera monitoring. A much more intensive monitoring programme is needed to describe flight patterns around turbine towers with this technology.

## Bat carcasses search and fatality estimates

The search efficiency trial showed that the tracker dogs found 82% of the test carcasses. This efficiency is comparable to other evaluations of the use of dogs to recover bat fatalities at wind turbines at sites with high to medium visibility, i.e. sites where the vegetation is < 50 cm high (Arnett 2006, Mathews et al. 2013).

No bats were recovered during the 15 carcasses searches in 2013. As no carcasses were recovered during the searches, the total bat fatality rate at the wind turbines in Østerild was not estimated.

Collisions will inevitably occur, but the probability to detect them is low if collision rates are low. However, even very low collision rates of an average annual mortality rates per wind turbine of less than one individual per species, which has been recorded on Germany, is sufficient to significantly impact the affected bat populations negatively both at local and national level (Seiche 2008, Dürr 2009, Rydell et al. 2011).

# Conclusions

## Bat occurrence and activity levels

The overall species composition and occurrence of bats at the monitoring sites in the test centre area and its vicinity in 2013 were similar to the baseline survey in 2011. *Myotis*-bats and Nathusius' pipistrelle were the most commonly recorded species. *Myotis*-species recorded included pond bat and Daubenton's bat. On some nights all recorded *Myotis*-calls at wind turbine sites were pond bats. Six more species were recorded irregularly in the study area: soprano pipistrelle, serotine, brown long-eared bat, parti-coloured bat, noctule and Leisler's bat. The last three species were not recorded in 2011.

Bat activity levels at the monitoring sites in the forest were similar in 2013 and 2011, while the bat activity levels at the ponds were significantly higher in 2013 than in 2011. At the ponds the activity was dominated by pond bats and Daubenton's bats. Up to 80 % of the recorded calls were pond bats. The ponds constitute highly important foraging sites for the local pond bat and Daubenton's bat populations throughout the summer and autumn, and possibly also in spring and early summer.

The bat monitoring in 2011 and 2013 suggests that there have been no negative effects on occurrence of bats in the wind turbine centre after the first year of operation.

High bat activity at wetlands – whether they are existing wetlands or newly constructed once as part of the implementation plan for a wind turbine facility – near the wind turbines increase the risk that the bats may find and exploit resources around the turbines and the risk for collisions, which will increase the risk of negative effects on the status of affected bat populations.

## Bat activity near turbine towers

A higher bat activity was recorded around the wind turbine towers than along nearby forest edges and around the open-structured meteorological masts. These results suggest that bats are attracted to the turbine towers and spend time to investigate and forage around the towers, i.e. increasing the risk of collisions by the rotating wings, if the bats climb to rotor height. However, the sample size for these analyses is low, and further studies on the bat activity at different distances from the turbine towers are being carried out in 2014.

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# Part B:

## First year post-construction monitoring of birds at Wind Turbine Test Centre Østerild

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# Introduction

In June 2010, the Danish Parliament passed a Public Works Act to establish a national test centre for wind turbines near Østerild in Thy, Denmark. This legislation requires that an environmental monitoring programme should be implemented.

Since 2011, the technical facilities at the test centre have gradually been developed and various structures erected on site. The test centre comprises a total of seven test sites for wind turbines of up to a maximum height of 250 m. Each test site consists of a single wind turbine, each with a mast for measuring equipment (up to 150 m in height) located immediately to the west of each turbine.

The test centre also comprises two masts supporting meteorological equipment at heights up to 250 m secured with guy-wires. These masts are also used for aviation safety lighting.

The Department of Bioscience at Aarhus University was commissioned by the Danish Nature Agency to undertake a monitoring programme of birds in the test area. The monitoring programme comprises one baseline (2011/12) and two post-construction study periods (2013/14 and 2015/16).

In 2012 we presented the results of the baseline monitoring programme, which was undertaken to establish a baseline reference for the future analysis of the potential impacts on birds caused by the operation of the test centre and to provide a preliminary risk assessment for relevant species (Therkildsen et al. 2012).

On the basis of this preliminary assessment, which used crude estimates of collision risk, we considered the potential impacts of the combined structures on the bird species occurring in the study area unlikely to be significant.

Here we present the results from the first year of the post-construction monitoring programme, which was carried out from August 2013 until October 2014, together with an intermediate assessment of the potential impacts of the test centre on the bird populations occurring in the study area.

The test centre has not yet been fully developed and therefore the assessment considers a situation where around half of the planned wind turbines have been put into operation. All masts had been established when the first post-construction study year was initiated.

# Methods

## Wind Turbine Test Centre Østerild

### Turbines

The test centre is located in the Østerild Plantation in northwest Jutland, Denmark, and comprises seven north-south orientated sites on which turbines can be erected (Fig. 1). The average distance between sites is 600 m. A maximum of seven turbines may be in operation at the same time. The centre is allowed to erect turbines that reach an altitude up to 250 m at the upper wing tip, with rotor diameters of up to 220 m.

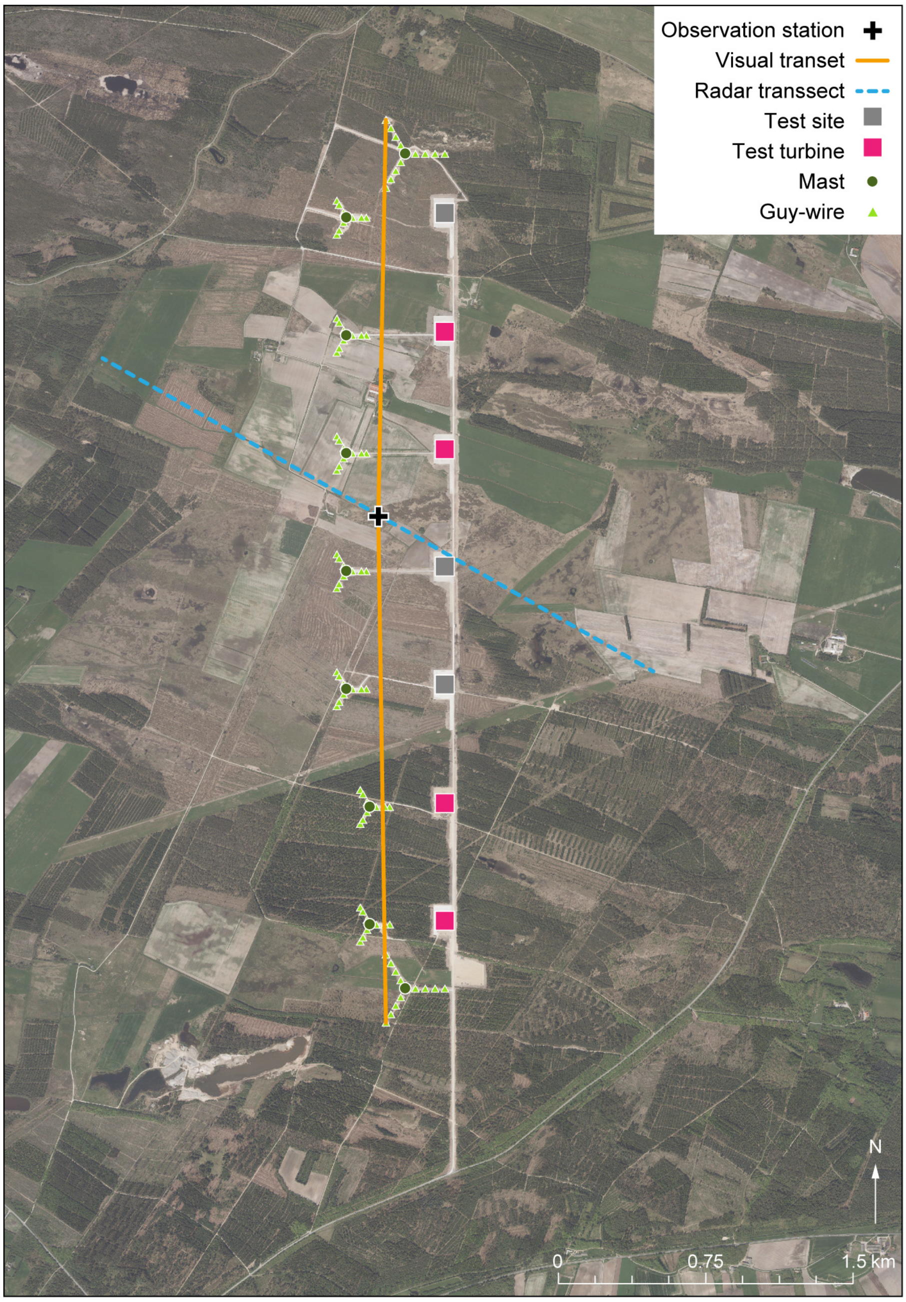



**Figure 1.** Wind Turbine Test Centre Østerild showing positions of wind turbines, associated structures, observation station, visual and vertical radar transects used for the data collection.

During the post construction study period from August 2013 until October 2014 the test centre has had the following configuration, which has been used in the assessment:

Site 1: Not in operation
Site 2: Vestas V164 from January 2014 onwards
Site 3: Vestas V126 throughout the study period
Site 4: Not in operation
Site 5: Not in operation
Site 6: Siemens SWT 6,0-154 until May 2014
Site 7: Siemens SWT 4.0-130 throughout the study period.

### Associated structures

A mast supporting meteorological measuring equipment for the turbines is placed 500 m west of each test site (Fig. 1). Hereafter, we refer to these masts as “met masts”. The triangular lattice masts are 1.20 m wide on each side and of a variable height between 100 and 150 m. The pipes that make up the lattice structure have a diameter of 168 mm at the corners. The angled pipes that make up the lattice are 38 mm in diameter. The met masts are each secured with a number of guy-wires. Each set comprise up to nine guy-wires, dependent on the height of the mast. The cross sectional diameter of the guy-wires is 25 mm and they are anchored at different heights.

Masts supporting meteorological measuring equipment and aviation lights (hereafter “aviation masts”) are placed 360 m NW of the northernmost and 360 m SW of the southernmost turbine site, reaching a height of 250 m. The pipes and guy-wires are the same type as those used for the measurement masts. Each of the three guy-wire sets includes seven individual guy-wires.

### Lighting

Turbines and met masts have no lighting, whereas on each aviation mast there is a set of three strobe lights (covering 360°) at 90 m, 170 m and 250 m. The lights flash synchronously once a second (1 Hz). Intensity of lighting is variable: 200,000 Cd at daytime, 20,000 at dusk and 2,000 at night-time.

## Conservation issues

In general, collisions between birds and land-based wind turbines are expected to be most likely related to the following situations:

- During seasonal migration, where birds migrate over longer distances between breeding and wintering areas
- During local movements, where birds perform daily movements of shorter distance between feeding and roost sites
- When birds are disturbed by human activity
- When birds are attracted to wind turbines
- When birds undertake aerial pursuit of prey or are pursued by birds of prey.

The collision risk depends on numerous factors such as location and lay-out of the wind farm, size of turbines, landscape features, behaviour and morphology of the species and weather conditions.

Throughout the annual cycle large numbers of birds occur along the west coast of Jutland. In particular, the wetlands along the west coast are important breeding, staging and wintering areas for numerous species. During the migration periods in autumn and spring many species stage in the area for shorter or longer periods, whereas other species arrive in autumn and overwinter in the area until they return to the breeding areas in spring. The diverse range of species occurring along the west coast can be characterised by their different migration patterns. In general, the west coast forms a guide route for migration with waterbirds more likely to migrate over water, whereas land birds are more likely to migrate over land. Many waterbirds (e.g. geese, swans) and some landbirds (e.g. birds of prey, cranes) migrate during the day.

The baseline investigations confirmed that the test centre is not situated on a migration corridor, which is a result of the lack of topographical features to concentrate avian migration. Therefore daytime local movements accounts for more passages of birds at rotor height within the area than genuine seasonal migration. This means that regular daily movements between roosts and feeding sites by local birds are more important in relation to collision risk compared to annual movements undertaken by genuine migrants. Nevertheless, the design of the monitoring programme allows for an assessment of the collision risk associated with both types of migration/movement.

Other species, especially smaller landbirds (e.g. warblers, thrushes) perform nocturnal migration. Little is known about the migration that occurs over land at the test centre. However, in contrast to the well-known Danish migratory hotspots at Blåvand (autumn) and Skagen (spring), which represent geo-physical features known to concentrate migratory birds and form geographic bottlenecks for avian migration, real migrants were not expected to be concentrated at the test centre to any large extent. However, since collision risk may be elevated during periods of darkness, nocturnal migration in the area was included as a focal issue in the baseline programme. Our investigations showed that genuine nocturnal migration occurred in the study area, although the patterns indicated that the test centre is not situated on a migration corridor. The pattern of nocturnal migration merely suggested a broad-fronted movement of passerines, the magnitude of which was outnumbered by the activity of local birds around dusk. Since broad-fronted nocturnally migrating passerines are suggested to present a relatively low risk of collision (Desholm 2006), we assumed that this was also the case in the Østerild area.

The test centre is located near several Special Protection Areas (SPAs), which are sites designated for their particular importance for birds. These SPAs have been classified for rare and vulnerable breeding birds (as listed on Annex I of the EC Birds Directive) as well as for regularly occurring migratory species according to Article 4.2 of the EC Birds Directive and generally following the criteria for designation of wetlands of international importance. As result of their high conservation interest we have focused attention on this group of species in both the baseline and post-construction studies.

## Focal species

Initially, whooper swan, taiga bean goose, pink-footed goose and common crane, were included in the baseline investigations. However, on the basis of the results obtained during the baseline studies, white-tailed eagle and light-bellied brent goose were also included as focal species in the post-construction programme.

These six species share the following characteristics, which are relevant when assessing the potential impacts of increased mortality as a result of collisions with wind turbines:

- They are long-lived and slowly reproducing and therefore relatively more sensitive to added mortality
- They are relatively large birds with poor manoeuvrability
- They perform daily local movements between roosts and feeding areas in the immediate area
- Little is known about their local movements in the area.

### Whooper swan

North Jutland is an important wintering area for the Scandinavian and Icelandic breeding population of whooper swans. The flocks arrive in late October and numbers build up until midwinter, when peak numbers are reached. The whooper swans may leave the area during cold spells. The flocks leave the area in late March.

### Taiga bean goose

A small, isolated population of taiga bean goose numbering around 3,000 individuals, winters in Great Britain and western Denmark, part of which winters in Thy and Vejlerne. Denmark has a special responsibility to protect the population and a complete hunting ban has been introduced in north Jutland. Highest numbers of taiga bean geese occur in northwest Jutland in December-January, when some continue to Britain, although smaller numbers are present in the area until the birds leave the country to return to their breeding areas in April.

### Pink-footed goose

Northwest Jutland, in particular Vejlerne, constitutes an important area for pink-footed geese, which arrive from the breeding grounds in late September. In midwinter, particularly during cold spells, the flocks move further south along the west coast. Numbers build up in spring until the flocks leave the area in late April. The flocks perform daily movements between for example the SPAs in Vejlerne and nearby feeding areas in the farmland.

### Common crane

Thy and Han Herred, including Vejlerne, constitute an important area for common cranes (Fig. 2), which typically occur in the area from March until late November. In 2011, 31-35 pairs were breeding in Thy and Han Herred of which 6 pairs were found in Vejlerne (Kjeldsen & Nielsen 2011, Nyegaard 2012). In 2013, this number had increased to 11 pairs (Kjeldsen & Nielsen 2014)). From late August until late October a major aggregation occurs at Vejlerne (Kahlert et al. 2010). Little is known about the local movements between areas in the eastern part of Thy, where the test centre is situated.

**Figure 2.** Common cranes occur regularly in the study area. © Jørgen Peter Kjeldsen

### Light-bellied brent goose

Denmark is the most important wintering site for the East Atlantic (Svalbard) flyway population of the light-bellied brent goose, which breeds in the eastern and northern parts of Svalbard and to a lesser extent in northeast Greenland. In spring, the whole population assembles at a few staging sites in north-west Denmark. In the morning of May 26 2011, six flocks of 95, 60, 57, 35, 17 and 15 light-bellied brent geese migrated northwards within 2000 m of the test centre. The observation coincided with the northbound mass departure, which normally takes place under favorable wind conditions in late May (e.g. tail-winds from a southerly direction) (Clausen et al. 2003). Therefore, given the high conservation status of this population, light-bellied brent goose was included as a focal species in the post construction programme and in spring 2014, intense field work was carried out at the time of the expected mass departure of light-bellied brent geese.

### White-tailed eagle

During the baseline studies a white-tailed eagle was observed in the study area on one occasion. Therefore this species was not subject to further analysis. However, on the basis of the presence of a potential breeding pair in the vicinity of the test centre, white-tailed eagle was included as a focal species in case it occurred more often than expected in the study area. Indeed, regular observations of a pair of white-tailed eagles were made in the study area during the post-construction studies.

### Other species

With 5-6 breeding pairs registered in the study area in recent years (Niels Odder, pers. comm.), nightjar was identified as another focal species, which is also listed on Annex I of the EC Birds Directive. No attempt was made to collect data on nightjars during the baseline programme, whereas in the post-construction programme, data on the occurrence of nightjars was collected for a preliminary assessment of the potential impact of the test centre on this local breeding population.

Besides the focal species mentioned above, the study was designed to ensure that data were collected for all species occurring regularly in the study area. Therefore, other species were included in the analysis, if sufficient data were available or if species of high conservation interest occurred in the study area (see below).

## Study design

Apart from minor modifications and special efforts targeted towards specific focal species, the design of the post-construction programme was similar to the baseline programme, which aimed at generating species-specific data, whenever this was technically possible. For this reason, although data was partly collated from comprehensive automated recording processes, the collection of high quality and high resolution data was given priority at all times in the investigations and especially species-specific during both the baseline and the post-construction studies. We used visual transect counts, vertical radar and laser range finder data, which in combination provided the basic information for the ornithological assessment.

We use established methodologies to secure relevant high quality data to address the specific questions concerning birds. At the same time, we made sure that the methodologies used were accurate and reproducible, which ensured that post-construction and baseline data were compatible providing a reference for the final assessment of the potential impacts of the test centre on the bird species in questions.

As mentioned above we focused on obtaining data to support the assessment of potential impacts of the test centre and the associated structures on bird species of high conservation interest, i.e. bird species listed on Annex 1 of the EU Birds Directive and other regularly occurring migratory species.

### Visual transect counts

Visual counts have the advantage of providing a detailed quantitative species-specific description of bird migration during daytime. Throughout the study period, visual counts were carried out from a central observation station, along transects orientated in southerly and northerly directions situated between the turbine sites and met masts (see Fig. 1).

The aims of the surveys were:

- To provide data for the species-specific description of migration intensity of birds, which were incorporated in the first preliminary estimation and assessment of the avian risk of collision with turbines.
- To provide a species-specific description of the migration intensity at the location of the structures in the study area, in order to determine and describe species-specific behavioural responses to the presence of the structures.

In addition to the focal species initially included in the baseline programme, this method also ensured that data were obtained for all other species present in the area. On each transect all birds were counted during an observation period of exactly 15 minutes (Tab. 1). Subsequently, numbers were extrapolated to express a calculated number of passages for each time period (see Appendix B2 for details). Observers used binoculars and telescope.

The species-specific data on birds crossing the transects during 15-minute periods were combined with weather data, and the effects on avian numbers and movements of wind direction (SW, NW, SE and NE), wind speed, temperature, time of the day and month were analysed for selected species, using general linear models.

For each species a substantial proportion of the transect counts resulted in zero counts for some or all species. A linear model that accounts for excessive numbers of zero-counts comprises two components: 1) A logistic component that investigates the presence or absence of birds in relation to factors and 2) a component that takes into account the numerical response to the factors in the model. So to analyse the effect of temperature, wind direction and wind speed, we used a generalized linear model with a zero-inflated Poisson distribution. The zero-inflated model was used because the data set had an excess of zeros as most species only occurred in certain months. Month was used for the zero model, whereas the effect of wind direction and wind speed were modeled with a Possion distribution. We used proc genmod in SAS 9.3 to test the model.

The model could only converge for six species. The species for which the model could not converge could also not converge with simpler models where one of the wind parameters or temperature had been omitted. The lack of model convergence suggest that wind direction and wind speed had limited effect on the number of individuals that passed transects.

**Table 1.** The number of 15 minute transect counts carried out each month during the post-construction programme at the Wind Turbine Test Centre Østerild during daytime.

| | 2013 | | | | | 2014 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | August | September | October | November | December | January | February | March | April | May |
| North | 65 | 55 | 58 | 37 | 32 | 33 | 31 | 52 | 60 | 70 |
| South | 66 | 57 | 56 | 37 | 31 | 33 | 30 | 50 | 60 | 68 |
| Total | 131 | 112 | 114 | 74 | 63 | 66 | 61 | 102 | 120 | 138 |

### Laser range finder

A laser range finder (Vectronix, Vector 21 Aero ®) is an optical device that can instantaneously measure flight altitude, distance and angle to flying birds (distance capability: 12 km, range accuracy: ± 5 m, horizontal accuracy: 10 mils, elevation range: -30 to 90° (zenith); source: Vectronix AG, Switzerland). Sequential measurements of the same bird/flock returned the exact geographical location of each measurement, which can then be connected by lines to provide a three-dimensional mapping of the flight paths of birds. The device is hand-held and therefore data can be collected in all directions in contrast to a vertically operated radar unit that can only cover avian movements in airspace in two dimensions, unless the position of the entire antenna unit is re-orientated (e.g. horizontal to vertical mounting). Hence, a laser range finder is a very flexible and efficient device for gathering data on species-specific flight altitudes of the visible migration during daytime. Measurements of large birds or flocks e.g. cranes, geese and swans can be obtained at distances up to 3 to 4 km, while passerines can only be tracked at ranges of up to ca. 1,200 m. Thus, the limitations of the device relate to the reduced efficiency of the human observer to detect small birds at long distance and at high altitude. The laser range finder was therefore primarily expected to provide data on local movements of large birds (e.g. between foraging areas). However, the study area does not represent a daytime migration hot-spot for long-distance migrants, which show a much more diverse range, but typically higher flight altitudes than local movement of staging birds (Dirksen et al. 2000).

The aims of the surveys associated with laser range finder were:

- To provide data on species-specific flight altitudes of birds, which were incorporated in the estimation and assessment of the collision risk at turbines.
- To provide a species-specific baseline description of the flight altitudes, flight paths and distances in relation to the planned structures in the study area for comparison with baseline measurements in order to describe the behavioural responses to the presence of the structures.

Measurements with the laser-range finder were undertaken both during count sessions on transects (see above), whenever this was possible, and between count sessions during the entire study period. Measurements of altitude, distance and angle to a bird/flock together with the information on species and flock size were transferred to a GIS-platform (ArcMAP 10) to provide information on flight paths and to calculate the distance of flight paths and individual points of measurements to the nearest structure categorized as turbines, met and aviation masts together with guy-wires supporting these.

Only the mean flight altitude of flocks on which repeated measurements had been obtained was used to avoid pseudo-replication.

To test how wind speed, wind direction and temperature affect the altitude we used a general linear model as altitude could be expected to follow a normal distribution. The model consisted of wind direction, wind speed and temperature as dependent variables and altitude was the dependent variable. Temperature was the mean daily temperature for all observations except for radar observations. Wind speed was measured in m/sec, and wind direction was assigned to one of four groups (NE, SE, SW, NW) each with 45 degrees on both sides of the four directions. We analyzed the model for each species using general linear models (Proc GLM) in SAS 9.3 (SAS Institute, Cary, NC).

### Test for avoidance

Birds may avoid the wind turbines either by increasing altitude when approaching the wind turbines or through adjusting/changing the flight direction. The recent data obtained after construction of wind turbines were compared with the baseline observations (i.e. prior to the presence of wind turbines) for each species.

We used a general linear model to test if and how birds avoided the wind turbines. The dependent variables in the model that may affect altitude or flight direction, included minimum distance to the wind turbine during post-construction and distance to wind turbines during baseline, month, wind speed and the interaction between distance to the wind turbines and baseline versus post-construction:

Altitude = month wind baseline-vs-post-construction distance baseline-vs-post-construction*distance

The interaction allowed us to test if and how birds responded differently to the presence of wind turbines. A significant interaction indicates that the altitude relative to the distance to the wind turbines differed between baseline and post-construction i.e. whether the slope estimate for distance differed between baseline and post-construction. Month and wind speed are variables known to affect altitude (Therkildsen et al. 2012) and were therefore included as covariates to reduce the unexplained variance in the model.

Altitude was used as a continuous response variable and could be tested with a general linear model. Flight direction was assigned to one of four groups each covering 90 degrees of the circle (NE, NW, SW and SE) and tested with a generalized linear model assuming a multinomial distribution for wind direction. The dependent variables were the same as for the altitude model.

### Radar

In the post-construction programme we used a marine surveillance radar unit (Furuno FAR 2X27BB, X-band, 25 kW, 8 foot antenna) similar to the one which was used during the baseline study. Radars have the advantage of enabling detection of bird movements during periods of limited visibility as well as darkness, which makes the equipment very efficient in studies of nocturnal activity of birds. We therefore used vertical radar, providing data on flight altitude, to describe nocturnal bird movements on a small spatial scale around the test centre structures. It is essential to note that radar provides no direct species-identification of the birds, unless combined with visual observation (see previous section).

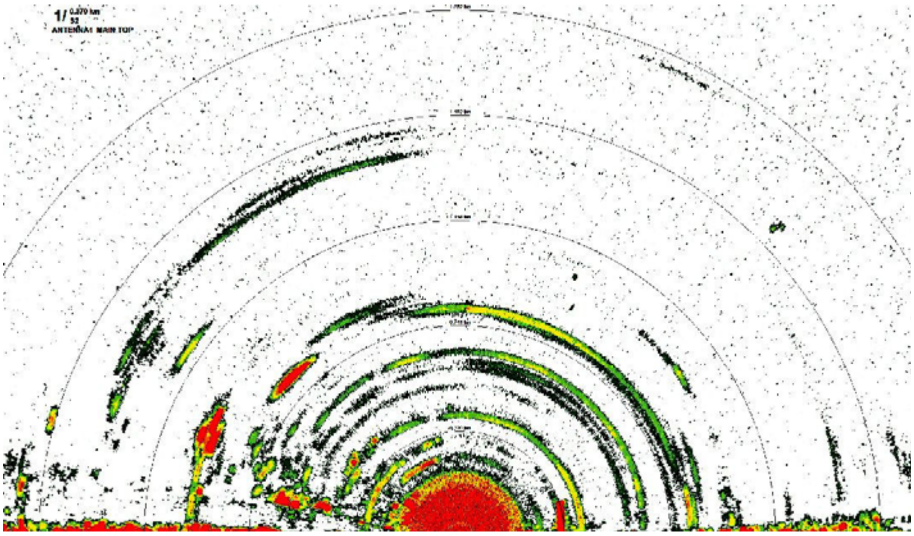
The aims of the surveys associated with the vertically operated radar unit (Fig. 3) were:

- To obtain measurements of flight altitudes and relative migration/ movement intensity primarily during night-time, when other methods are hampered by limited visibility
- To provide data as a reference for the assessment of the collision risk presented by the structures to nocturnal migrants.

Data on nocturnal migration were collected during the peak migration periods in autumn 2013 and spring 2014.


**Figure 3.** Vertical radar is used to provide data on flight altitude of nocturnal bird migration in the study area. © Henrik Haaning Nielsen.

**Figure 4.** An example of the post-construction radar screen-dump images. Note the "layer" and "plumes" of warm echoes close to the ground and the many circular areas of warm and cool echoes that represent areas of clutter that are persistent for a session but occur with different placements and extents for the different sessions. On the right-hand side, at mid-level there is an echo that represents a bird.



Data were collected along a NW-SE-orientated transect (Fig. 1) and the radar range was set to 1,852 m - the maximum distance over which birds could be detected without compromising the conspicuousness of bird echoes. The data collection was based on an automated minute-by-minute screen-dump system that archived the echoes detected by the radar (Fig. 4). An object-based image analysis (OBIA) was undertaken of each of the screen-dump images from each session using the OBIA software Trimble eCognition v.9 (Trimble 2014). In the screen-dump images echoes are represented by areas of colour against a pale background, with warmer colours representing stronger echoes. The developed OBIA procedure was initiated with a quadtree segmentation, to identify as objects the detail in the image. Objects having warm colours were merged to form echo "blobs", i.e. echoes of birds and other target features. All other objects, plus smaller (i.e. objects known to be too small to represent a flying bird) warm objects, were merged to form the background object(s). By this analysis, each image was simplified to a representation of just the blob echoes and the background. False echoes and echoes from landscape elements (tree, buildings etc.) were removed from the echo set by application of a session-mask representing the parts with static echoes (so-called "clutter"). An initial mask was applied as part of the OBIA processing to remove parts beyond 1,852 m from the radar and parts less than 740 m from the radar (an area that is always highly clutter affected). A post-OBIA mask for a session was made by post-processing of the full initial sets of echoes from each session's set of images. As there was a high degree of low height level (0 - 50 m) clutter in the post-construction images, the clutter masking procedure (manual selection of parts with dense nests of echoes, representing clutter) that was applied to the baseline sessions' image data was not appropriate: that would have resulted in most of the lower 200 m of bird echoes being masked-away in most sessions. Thus, a new post-OBIA masking procedure, customised to the post-construction sessions' image data, and involving post-processing of the full initial sets of echoes from each session's set of images was developed and applied for each session. A cross-check made by application of the new (post-construction) clutter masking procedure on the image data of one baseline session (Fig. 5), with comparison of the resulting sets of bird echoes, showed that the two procedures were equivalent in their mapping of bird echoes. The set of blob echoes from the images of each session were merged (ERSI ArcMap 10.2).

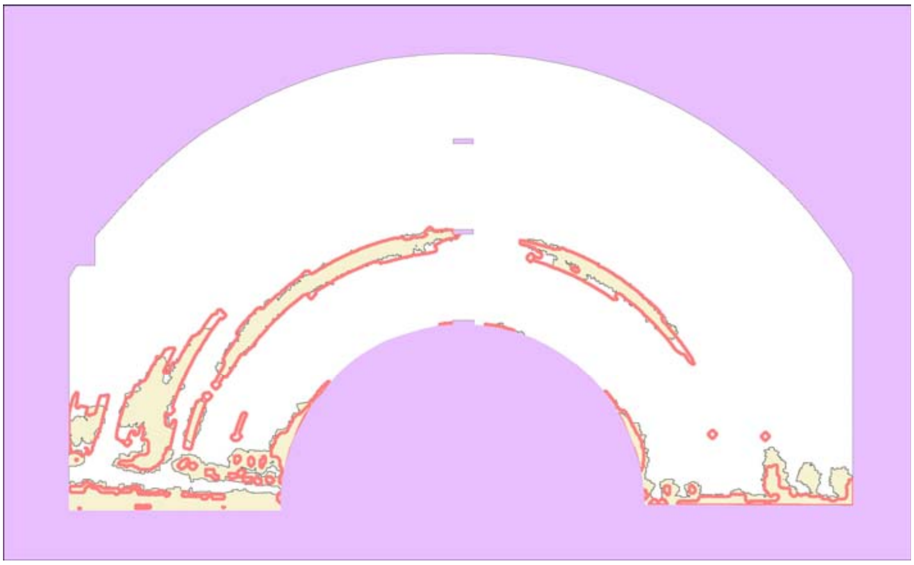


**Figure 5.** Comparison, for one session of radar images, of the clutter mask made by the masking procedure used for the pre-construction (baseline) image analysis (grey outline) and that used for the post-construction image analysis (pink outline). Note the similarity between the masks made by the two different procedures. For the post-construction image analysis, application of the mask was followed by removal by manual selection of remaining nests of apparent clutter. The purple area represents the initial mask, the same for all sessions, of parts beyond 1,852 m from the radar and parts less than 740 m from the radar.

The air space covered by vertically operated radar is a half circle above the ground with the centre at the observation station (Fig. 1). The angular breadth of the radar beam is 20°. Altitude intervals were therefore not equally covered. In order to correct for this bias, altitude intervals of 50 m were established, and the beam coverage in these intervals was calculated for each angle of the radar antenna (0-90°, increment 1°). This correction factor was calculated excluding areas with clutter. Finally, an overall correction factor based on the coverage of altitude intervals was derived and multiplied by the number of bird echoes in the altitude intervals.

Due to a substantial amount of clutter the radar beam coverage at 0-50 m was very small and excluded from the analysis (for discussion of the efficiency at low altitude of vertically operated radar – see Hüppop et al. 2004). Few bird echoes were observed between 1,500 and 1,850 m and this interval also had low coverage of the radar beam given the settings of the radar.

Therefore, data from this altitude interval were also excluded to reduce the potential bias by multiplying a large correction factor on a small number of observations. Altitude profiles (proportion of echoes at different altitude intervals) and overall estimates of the migration intensity (number of bird echoes per screen-dump per $km^3$ airspace) were calculated from the standardized data set. The effects on nocturnal flight altitudes and migration intensities from wind direction (SW, NW, SE and NE), wind speed, temperature and time of the night were analysed using general linear models. All possible combinations of factors were investigated in the modelling process and the most parsimonious model was selected, using Akaike's information index. The factor "time of the night" was squared as a curve-linear relationship with flight altitude and migration intensity was expected, based on the experience from other studies.

### Carcass searches

To quantify fatality rates we conducted carcass searches using trained dogs in plots under turbines, met and aviation masts. This is a method which has been widely used to determine bird fatality rates at wind turbines (Nievergelt et al. 2011 and references therein). Plots were centred at the base of each structure and covered a radius of twice the height of the mast or turbine. In some parts of the plots the vegetation cover was very dense and therefore inaccessible to dogs. No attempt was made to search these areas. We placed plots under the following structures:

Northern aviation mast (9.8 ha, 50%)
Met masts east of sites 2 (6.2 ha, 100%) and 4 (3.8 ha, 100%)
Turbines at sites 3 (10.1 ha, 100%), 6 (3.3 ha, 27%) and 7 (3.9 ha, 40%).

Numbers in brackets indicate the approximate proportion of the plot searched by dogs and the equivalent area. In total, an area of approximately 37 ha was covered on each search. All searches were initiated around sunrise.

Searches were conducted in the following time periods at 3-4 days intervals (the number of searches in brackets):
September 5 – November 5 2013 (n=17)
April 28 – June 5 2014 (n=12)
July 21- August 29 2014 (n=12)
September 18 – October 9 2014 (n=8).

Any carcasses found had their position recorded with GPS and were photographed. Carcasses were collected and kept at -18 °C for potential post-mortem analyses or identification, e.g. DNA analysis.

On November 6 2013, we conducted a field test of the dogs to assess their ability to find carcasses. A total of 28 bird wings, typically of dabbling ducks, e.g. mallard and teal, were randomly placed in all plots, which were subsequently searched.

In addition, we carried out removal trials to assess the persistence of carcasses. We placed carcasses of 50 female pheasants throughout the study area and visited them on a daily basis to quantify the rate at which carcasses were removed by scavengers. Each carcass was visited daily and the trial continued until all carcasses had been completely removed.

### Registration of nightjar territories

In July 2014, we registered advertising males of nightjars along a north-south orientated transect in the central part of the study area. All advertising males were positioned on a map and their flight altitude was either measured using laser range finder or estimated to be below or above treetops.

### Estimation of the number of collisions

#### Wind turbines

Modelling of the collision risk was undertaken for the selected species based on the data collected on the count transects and measurements of flight altitude using the Scottish Natural Heritage models (Band 2000). Desholm (2006) demonstrated that the avoidance response of a bird when approaching a wind farm was the single factor that had the greatest impact on the collision risk. Some information on species-specific avoidance response rates exist on geese from a recent local study (Kahlert et al. 2010). However, in most cases we adopted the values recommended by the Scottish Natural Heritage (Urquhart 2010). Thus, for the selected species the avoidance rates incorporated in the collision models varied between 97.75 and 99.00%.

The collision models developed by Scottish Natural Heritage offer two forms of assessment dependent upon turbine arrangement and bird flight patterns (Band 2000). The first, most simple model simulates a predictable passage of birds across a single row of turbines. The alternative model is used for bird species that may use a wind farm area in a more unpredictable manner, (e.g. a feeding area), which incorporates the time that an individual bird may remain within the confines of the wind farm area, potentially of more complex geometry (e.g. with turbines in one row or multiple rows). In general, the alternative model leads to an elevated risk of collisions compared to the simple model.

The modelling of the collision risk is described in detail in Appendix B2.

In order to explore the flight patterns at the test centre in further detail, the flight directions observed during the baseline study were used in a random simulation of passages of the wind farm area (using ArcMAP 10). Assuming that the flight directions would be the same after construction of the test centre, the simulation predicted that on average birds would only be at risk of colliding with one turbine at each flight episode. This was confirmed likely to be the case, by the general flight pattern, which showed a general tendency to pass the wind farm area along an E-W axis. It should be noted that this assumption may be violated during the operation of the turbines as flight direction may change due to avoidance.

For this reason the simple model was applied to geese, swans, common crane and cormorant, which typically crossed the wind farm area showing a consistent flight direction. The alternative model is typically used for birds of prey, which could potentially cross the single line of wind turbines several times during a foraging bout. In the present report the alternative model was applied to buzzard, hen harrier, marsh harrier, kestrel, peregrine falcon, common raven and small non-corvid passerines. In addition, it was applied to wood pigeon, which may also potentially undertake the same flight behaviour.

The results from the transect counts were converted to the number of birds crossing the row of turbines, which was incorporated in the model (see description of parameter in Appendix B2, which included an extrapolation of the migration intensity during observation periods to the remainder of the hours with daylight (sensu Band 2000 and see also Appendix B2 for further details of the extrapolation). Data were collected evenly throughout the daylight period. The daylight correction was applied on a monthly basis as the mean of daylight hours. The flight altitudes were used to derive the proportion of the birds that actually actively flew at altitudes with a risk of collision (i.e. the sweep area, min. 45 - max. 222 m). Further steps were undertaken in the calculation (see details in Band 2000) to estimate the number of collisions without avoidance response. Finally, avoidance was incorporated in the model and corrections made for periods of turbine inactivity due to low or high wind speeds (operational at 3-25 m/s based on in situ data) and when maintenance was carried out (1 day per month).

### Associated structures

Bird collisions at towers and masts have been subject to extensive research, especially in North America. Nevertheless, predictive models, comprising the same detailed features as collision models for turbines, have not been developed, probably because of the complexity of the issue. For example, it would be a questionable approach just to calculate the number of collisions on the basis of the amount of airspace that is occupied by the structures, cf. the principles used in the collision models for turbines. Thus, guy-wires occupy a relatively small amount of airspace compared to the main tower or mast (Fig. 6), yet they seem to be considerably more hazardous to migrating birds than the tower or mast structures themselves (e.g. Avery et al. 1976), most likely because guy-wires are difficult to discern even at daytime (for example when they appear to offer little visual contrast against a background of grey clouds).

**Figure 6.** A white-tailed eagle perched on a tree in the study area. A met mast with guy-wires is seen in the background. © Henrik Haaning Nielsen.

Given our great lack of knowledge with respect to bird collisions at towers or masts in Denmark, a meta-analysis of North American studies undertaken by Longcore et al. (2008) was used to at least provide a crude estimate of the expected number of casualties at met and aviation masts at the test centre. This meta-analysis confirmed the hypothesis that the number of casualties increased significantly with the height of the structure. By describing this relationship as a mathematical function (linear regression of the logarithm to the number of casualties and mast height), the heights of the Østerild masts could be inserted in the function ($y = 0.0121*HEIGHT^{1.7763}$, $R^2 = 0.25$) in order to derive a prediction of the expected order of magnitude of collisions. The use of this approach should be used with great caution and the results can only be considered as a rough guideline. For example the migration intensity could also affect the number of casualties at tall towers or masts. This factor was not incorporated in the equation, and hence we assume that migration intensities are comparable between North America and Østerild, which is unlikely to be the case.

### Overall considerations regarding collisions with other structures

In the following, we present estimates of the number of collisions at turbines for each species included in the post-construction analysis (see species account below). However, as was the case in the baseline report, we only provide an overall prediction, which includes all species registered in the study area, for the number of collisions with other structures (met and aviation masts) (Tab. 2). See pages 54-55 in the baseline report (Therkildsen et al. 2012) for a full evaluation of the collision risk between birds and structures at the test centre.

**Table 2.** Crude estimates of the predicted annual number of bird casualties at masts in the Østerild Test Centre.

| Type of structure | Height (m) | Number of structures | Predicted annual number of casualties |
|---|---|---|---|
| Aviation masts | 250 | 2 | 440 |
| Met masts | 100-150 | 7 | 302-621 |

### Meteorological data

Data on wind conditions and temperature are important factors that are known to affect flight behaviour and the general occurrence of individual bird species in the study area. Thus, strong headwinds relative to the prevailing direction of migration is likely to reduce flight altitude and migration intensity of birds (Kahlert et al. 2012a). Several species are sensitive to cold spells (temperatures below 0 °C) during the winter, as this may hamper feeding opportunities and initiate southward migration of birds. For this reason, it was considered important to model the effects of meteorological variables on flight movements of different species.

On each observation session cloud cover, visibility and precipitation were recorded. It was not possible to obtain data on wind speed, wind direction and temperature from the study area. In order to ensure consistent data sets across the study period, these weather data were therefore obtained from a weather station in Hanstholm, ca. 18 km NW of the study area (courtesy of the Danish Meteorological Institute; data collected at a height of 22 m above the ground).

### Quality assurance and data storage

Quality assurance measures were integrated in all stages of both the baseline and the post-construction studies. This included all steps from the initial collection of data in the field, during data entry and analysis, until the final report writing. Field observers were responsible for entering data thereby inspecting their own data forms for accuracy. The electronic database was inspected using SAS/STAT statistical software (SAS Institute, Cary, NC) and any errors detected were corrected. Statistical analyses, including modelling, were performed using SAS/STAT statistical software. A database and a GIS platform were developed to store and organize data. All data forms, including field notebooks, and electronic data files were retained for future reference.

# Results

## Meteorological observations

### Cloud cover

In about 60% of the observation sessions the cloud cover was 5/8 or more and only around 16% of the observations were made when the sky was clear. Since smaller birds are particularly more easily detected on a cloud covered sky compared to a clear sky, observation conditions with respect to cloud cover were good at most times (Fig. 7).

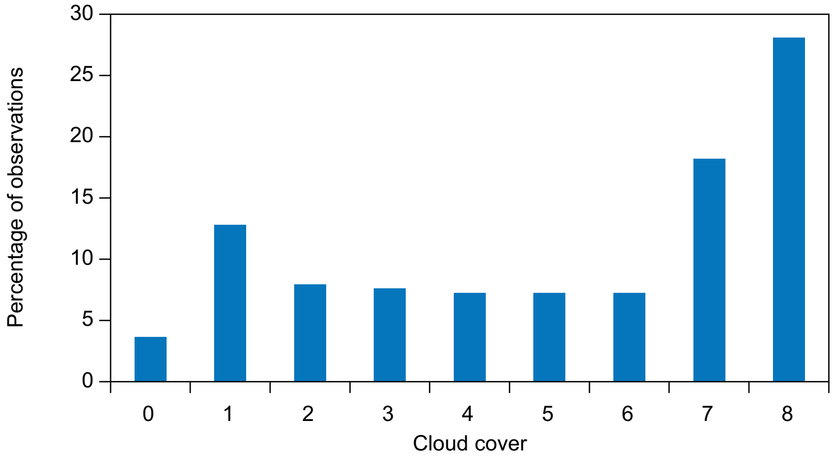



**Figure 7.** Cloud cover recorded during field work in the study area from August 2013-May 2014.

### Visibility

In general, the visibility recorded during field work was good and in more than 90% of the sessions visibility was more than 5 km (Fig. 8).

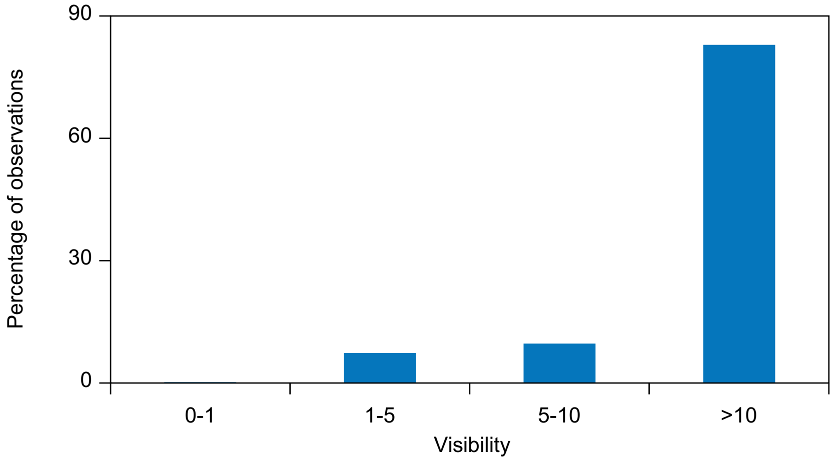
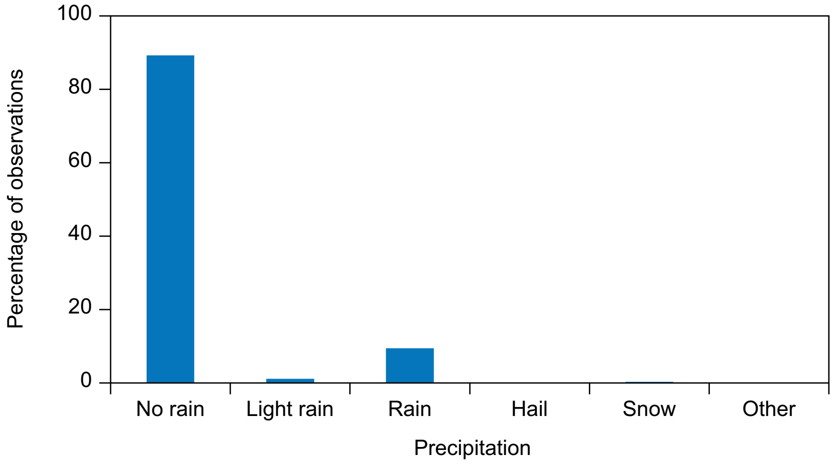



**Figure 8.** Visibility recorded during field work in the study area from August 2013-May 2014.

### Precipitation

Almost 90% of all observation sessions were made during periods with no precipitation (Fig. 9).

Figure 9. Precipitation recorded during field work in the study area from August 2013-May 2014.




Overall, observation conditions were favourable, which reflect the fact that observation days were chosen to ensure that sufficient data were collected during the post-construction programme. However, it should be noted that weather conditions showed some variation, which means that occasionally observations were made during periods with rain or light rain, which hampered visibility accordingly.

### Wind conditions and temperatures

In late summer and autumn 2013, the direction of the wind generally showed great variation with winds from both easterly and westerly directions, although prevailing winds were from a south westerly direction. In winter 2013/14, prevailing winds were from a southerly direction, although a cold spell in late January was caused by a longer period with winds from an easterly direction. In spring 2014, the direction of the wind showed great variation. Prevailing winds were from a southwesterly direction, although in late spring there were periods of shorter duration with easterly winds particularly in late March-early April and in late April (Fig. 10).

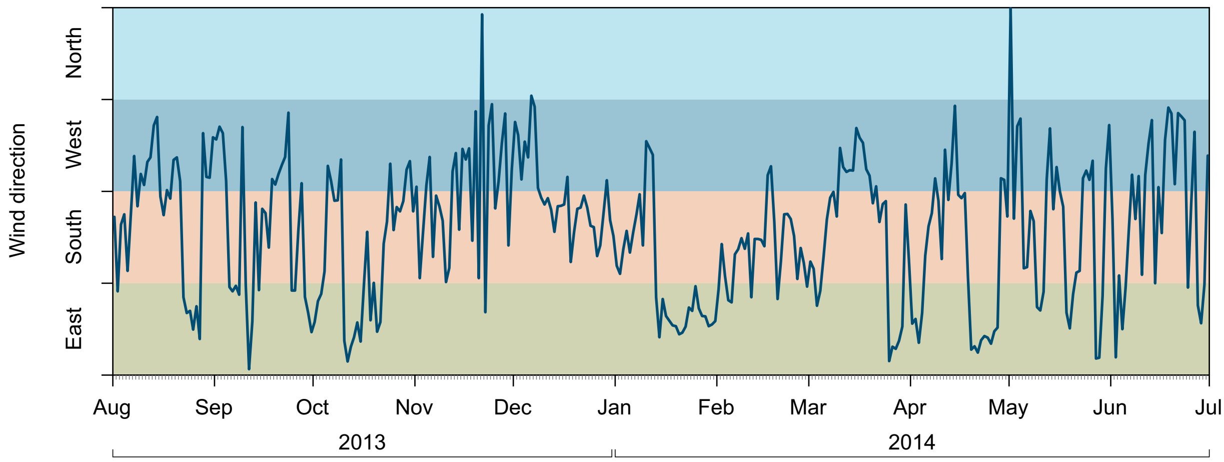



**Figure 10.** Daily mean wind direction broken into four main directions. Data were compiled at a met mast in Hanstholm from August 2013-June 2014. Data from the Danish Meteorological Institute.

In late summer and autumn, mean daily temperature decreased from approximately 15-25 °C in August to 5-10 °C in November. In winter, mean daily temperature was rather stable at around 6 °C, except in late January, when temperatures dropped below 0 °C.

In spring, mean daily temperature increased from approximately 7 °C in March to 15 °C in late May (Fig. 11).

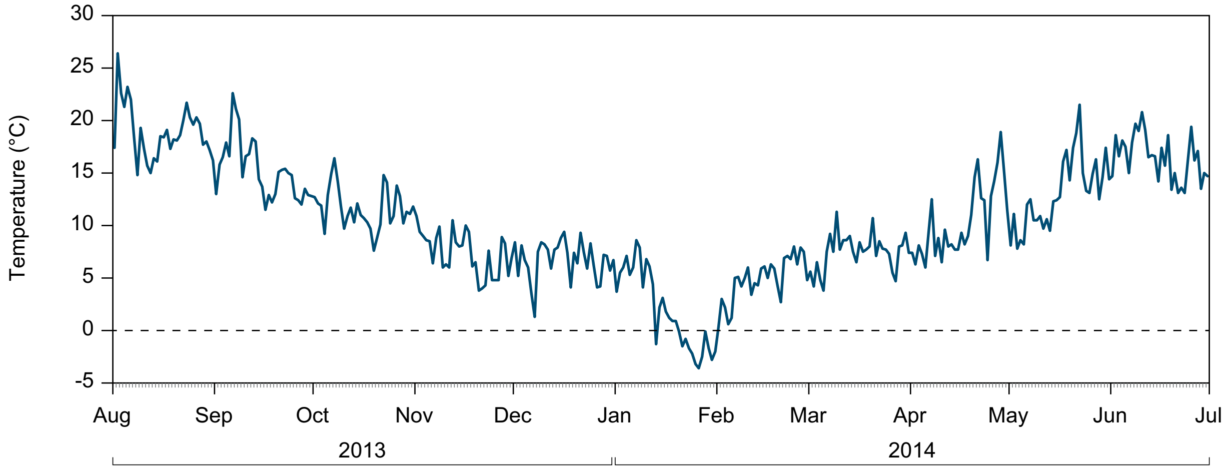



**Figure 11.** Daily mean temperatures based on data compiled at Hanstholm from August 2013-June 2014. Data from the Danish Meteorological Institute.

Altogether, autumn 2013 in Denmark was somewhat warmer than normal with average temperatures at 9.9 °C, whereas winter temperatures in 2013/14 were the second highest ever recorded. Likewise, spring 2013 was the second warmest ever recorded with mean temperature at 8.7 °C, which is 2.5 °C above the normal (Danish Meteorological Institute).

## Carcass searches

No carcasses were found during the searches. However, one un-identified thrush was found during the field test of the dogs, whereas a common swift was found in connection with other field activities on August 7 2014. Both fatalities were most likely a result of a collision with turbines.

The removal trials showed that by the 3rd day, 50% of the carcasses had been removed. On the 6th day around 25% of carcasses remained, whereas by the 15th day, no carcasses remained.

The field test of the dogs showed that 79% of all bird wings were retrieved. The wings that were not retrieved were typically from smaller ducks, e.g. teal, and were those placed in high vegetation.

The fact that no fatalities were found during the carcass searches may reflect the following situations:

- No collisions took place
- Carcasses landed outside the search area
- Carcasses were broken by the impact into too small fragments to be detected by the dogs
- Carcasses were removed by scavengers prior to the searches
- Dogs were unable to detect carcasses.

We consider the complete absence of collisions between birds and the structures at the test centre during the periods when searches were conducted to be highly unlikely. We therefore assume that either some fatalities were missed by or were not available to the dogs or they were removed by scavengers between searches. Nevertheless, the results from the carcass searches indicate that the number of collisions is probably rather small.

On this basis the carcass searches confirmed the overall conclusions from the baseline studies that the wind turbines and associated structures will only result in a relatively small number of collisions with birds.

It is important to note that even though the carcass searches took place during the peak migration period in spring and autumn, not all weather conditions were covered. This is important, since most collisions have been reported to take place during adverse weather conditions (Newton 2007). Therefore, even though mass mortality resulting from collisions with physical structures is a rare event, this may have potential negative impacts on the affected populations. This is particularly the case for the larger, long-lived species with a low reproductive rate and those species that are local residents where such mortality may have disproportionate effect on local abundance. In this context, it is worth mentioning that in many cases the more sensitive species occurring in the study area, e.g. white-tailed eagle and common crane, are also more likely to be retrieved by search dogs than smaller, less sensitive passerine species.

Carcass searches will also be included in the last part of the post construction studies. Therefore, in the final post-construction report we will present a more detailed analysis taking into account the results from the carcass searches, removal trials and field tests of the dogs.

## Results on selected species

Besides the focal species mentioned above a number of species and one species group were included in the analysis either on the basis of their regular occurrence in the study area or because of their elevated conservation status, e.g. one or more SPAs have been designated for the species in the vicinity of the test centre. The species or species groups, which have been included in this first post-construction report is listed below. The list is not identical to the one presented in the baseline report because of changes in the occurrence of the species in the study area:

- Cormorant
- Whooper swan (focal species)
- Tundra swan
- Pink-footed goose (focal species)
- Taiga bean goose (focal species)
- Greylag goose
- Light-bellied brent goose (focal species)
- White-tailed eagle (focal species)
- Peregrine falcon
- Kestrel
- Marsh harrier
- Hen harrier
- Buzzard
- Common crane (focal species)
- Golden plover

- Wood pigeon
- Common raven
- Passerines (corvids, swallows, larks, wagtails, pipits, etc.)
- Nightjar
- Nocturnal migrants.

A total list of the bird species registered during the post-construction programme is presented in Appendix B1, which also provides scientific and Danish names for all species. It should be noted that since the occurrence and, therefore, the amount of data collected for individual species, varies, the level of detail and the robustness of the analysis differs markedly between species.

## Cormorant

### General occurrence

In 2013 and 2014, the number of breeding pairs of cormorant in Denmark was 24,702 and 30,503, respectively (Bregnballe & Therkildsen 2014). In Vejlerne, 784 and 710 pairs were breeding on the island of Melsig in nearby Arup Vejle in 2013 and 2014, respectively. Although this is somewhat fewer than in recent years, the colony is still the largest in the area. Danish cormorants leave the country to spend the winter in central Europe and the Mediterranean Sea. Outside the breeding season cormorants from Norway occur in Denmark. The Danish and Norwegian cormorants represent two different sub-species, *Phalacrocorax carbo sinensis* and *Phalacrocorax carbo carbo*, respectively.

**Figure 12.** Cormorants commuting between the colony at Melsig and feeding areas in western Thy and Skagerrak. © Jørgen Peter Kjeldsen.

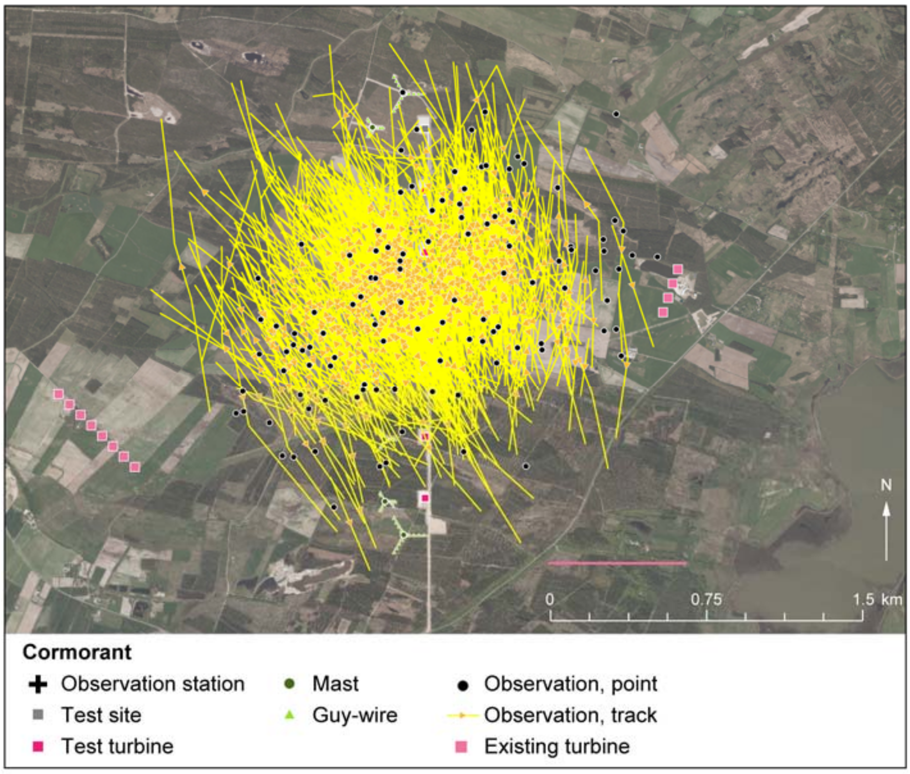
### Temporal and spatial patterns of occurrence in the study area

Cormorants occurred in the study area during August-November and from February to May. In December-January the cormorants left the area. Highest numbers occurred in late spring, which was also the case during the baseline studies (Tab. 3).

**Table 3.** Numbers of cormorants passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 349/10098 | 202/5629 | 458/10127 | 5/131 | 0/0 | 0/0 | 6/206 | 67/1892 | 150/4289 | 310/9072 |
| South | 232/6611 | 790/21241 | 194/4443 | 24/631 | 0/0 | 0/0 | 5/177 | 79/2320 | 134/3831 | 288/8676 |
| Total | 581/16709 | 992/26870 | 652/14570 | 29/762 | 0/0 | 0/0 | 11/383 | 146/4212 | 284/8120 | 598/17748 |

**Figure 13.** Overall flight patterns of cormorants in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (1,298 m) from the observer within which 90% of the observation points were located.




Altogether, 64.3% and 60.6% of the observed individuals and flocks, respectively, of cormorants occurred at rotor height (min. 45 - max. 222 m), whereas 35.7% and 39.4% of individuals and flocks, respectively, were outside rotor height (Fig. 14).

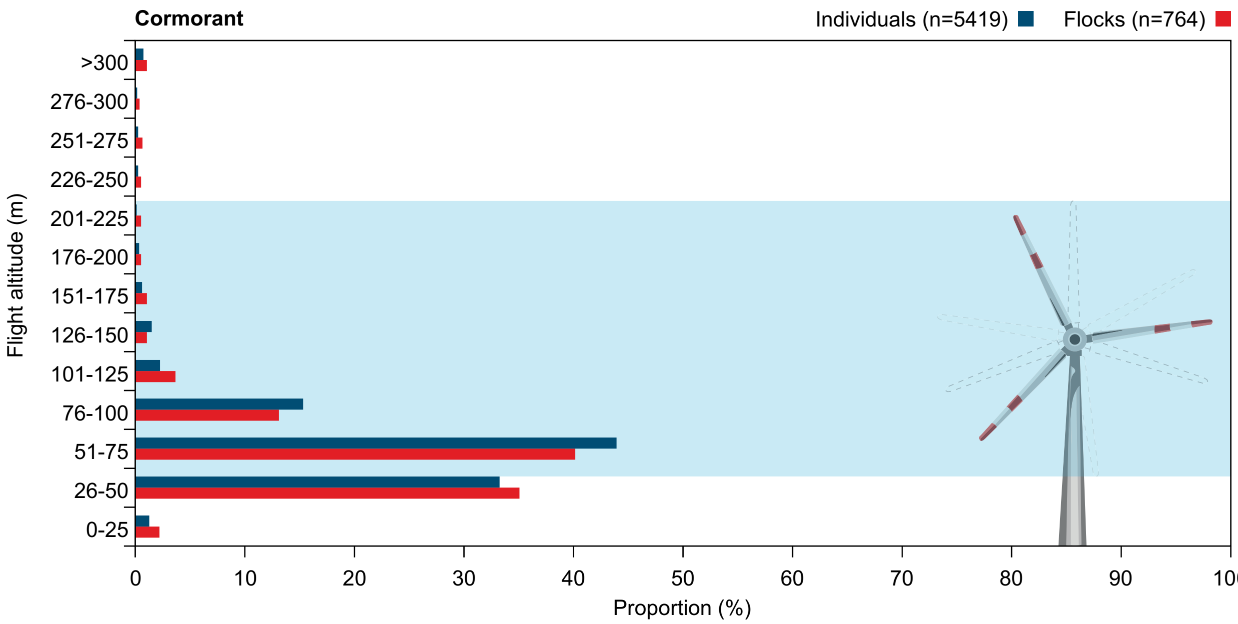



**Figure 14.** Flight altitudes of cormorants expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

#### Avoidance

Our comparison of flight patterns of cormorants obtained in the baseline and the post-construction studies showed that cormorants did not alter their flight altitude in relation to the distance to the wind turbines and other structures during the post-construction study (Tab. B1)

However, during the baseline study cormorants increased their flight altitude when approaching the study area. It should be noted that this result is based on a rather limited data set (Tab. B2).

#### Estimate of collision risk at turbines and other structures

An estimated 6-14 collisions between cormorants and wind turbines are expected to take place each year. The estimate is comparable to the estimate obtained from the baseline studies (3), when considering that the baseline study only covered some of the time during which cormorants are present in North-west Jutland.

We are not able to establish the extent to which seasonal migration took place in autumn, although we assume that the majority of cormorants registered in spring were local birds, some of which were breeding at nearby Vejlerne. This is supported by the relatively low flight altitude observed among cormorants in the morning and the evening both during the baseline and the post-construction studies.

There may be an additional risk of collisions between cormorants and other structures at the test centre, e.g. guy wires and masts. This is particularly the case in situations where visibility is reduced due to adverse weather conditions and around dusk. However, in contrast to other species, e.g. geese and ducks, normally cormorants do not actively fly during the night, when risk of collision would be highest.

In contrast to the baseline study, the observation period post-construction covered the entire time period during which cormorants are present in northwest Jutland.

The post-construction study therefore confirmed the result of the baseline study that only few collisions between cormorants and wind turbines are expected to occur each year.

#### Intermediate assessment

The results from the post-construction study support our preliminary assessment that the potential impact of the structures at the test centre on cormorants is considered to be insignificant. However, it should be noted that on the basis of the regular movements of cormorants through the study area, data will continue to be collected during the post-construction programme to improve the level of detail in the assessment of potential negative effects of the test centre on this population.

### Whooper swan

#### General occurrence

The whooper swans that occur in North-west Jutland mainly belong to the Continental North-west European flyway population, which breeds mainly in Sweden, Finland and northwest Russia. Flocks arrive from October until November and return to the breeding areas in early spring. With the onset of cold weather and snow, the flocks migrate further south. Therefore the number of whooper swans wintering in Denmark shows considerable fluctuations between years (Pihl et al. 2006).

### Temporal and spatial patterns of occurrence in the study area

Whooper swans began to arrive to northwest Jutland in October and highest numbers were present in November. Whooper swans were still present in the area in March (Tab. 4).

**Table 4.** Numbers of whooper swans passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 0/0 | 0/0 | 2/44 | 21/552 | 32/848 | 13/367 | 39/1336 | 4/113 | 0/0 | 0/0 |
| South | 0/0 | 0/0 | 17/389 | 69/1813 | 6/164 | 17/480 | 16/567 | 5/147 | 0/0 | 0/0 |
| Total | 0/0 | 0/0 | 19/433 | 90/2365 | 38/1012 | 30/847 | 55/1903 | 9/260 | 0/0 | 0/0 |

Most whooper swans were observed close to the observation station, although flocks occurred throughout most of the study area. The flight pattern indicates that the majority of whooper swans were local birds commuting between different feeding areas and night roosts in the area (Fig. 15). The overall flight pattern of whooper swans is similar to what was observed during the baseline studies.

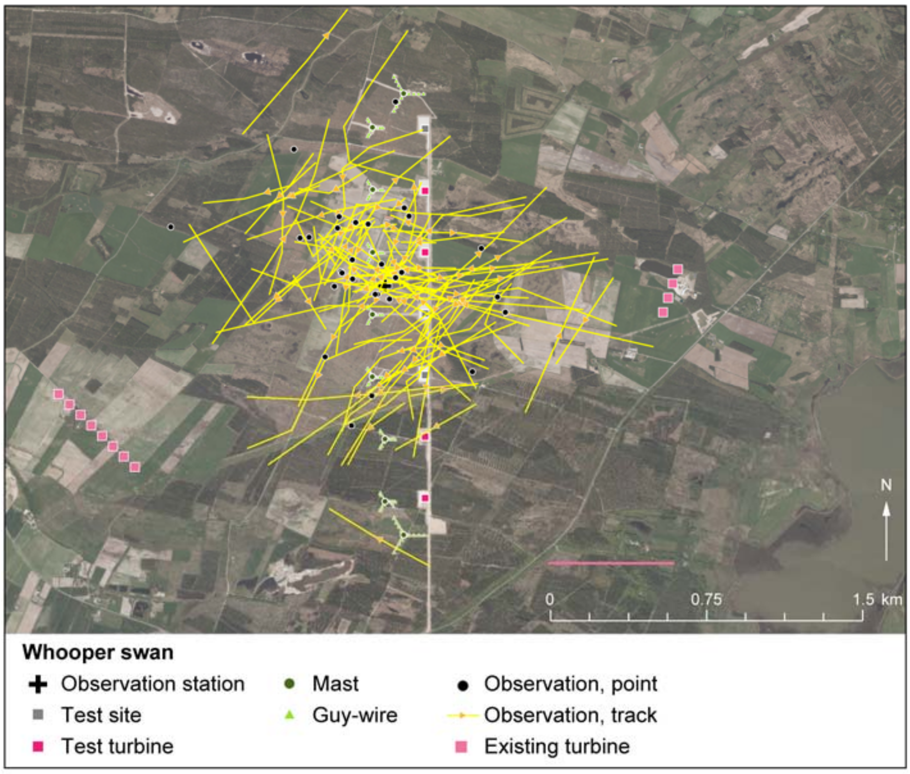



**Figure 15.** Overall flight patterns of whooper swans in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (1,195 m) from the observer within which 90% of the observation points were located.

Altogether, 13.6% and 18.3% of the observed individuals and flocks, respectively, of whooper swans occurred at rotor height (min. 45 - max. 222 m), whereas 86.4% and 81.7% of individuals and flocks, respectively, were below rotor height (Fig. 16).

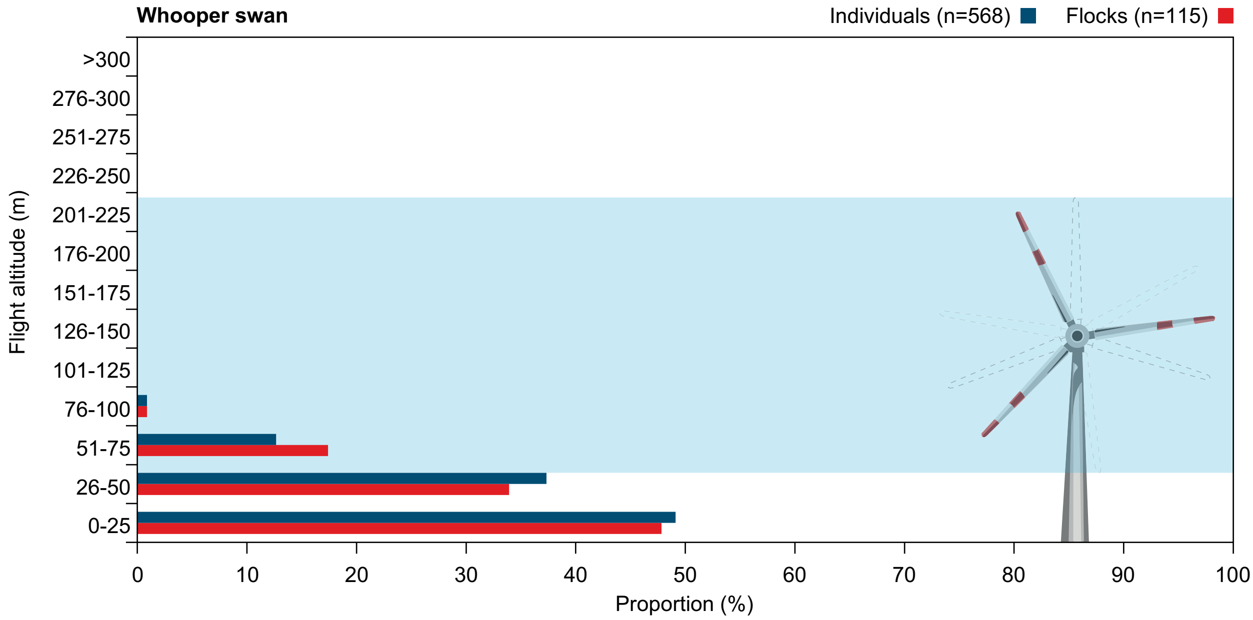



**Figure 16.** Flight altitudes of whooper swans expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

### Avoidance

When we compared flight patterns of whooper swans obtained in the baseline and the post-construction studies, there was no significant effect of 1) the distance and 2) the interaction effect between distance and the two study years (Tab. B1). The non-significant interaction effect indicates that whooper swans did not alter their flight altitude in relation to distance during the post-construction study compared to the baseline. The non-significant effects of distance suggest that whooper swans did not alter their flight altitude in relation to the distance to the wind turbines and other structures in general.

### Intermediate estimate of collision risk at turbines and other structures

An estimated 0.1-0.2 collisions between whooper swans and wind turbines are expected to take place each year. The estimate is lower than the estimate obtained from the baseline studies (4-9), although the baseline study covered only some of the time during which whooper swans are present in northwest Jutland. The post-construction study therefore confirmed the result of the baseline study that only a few collisions between whooper swans and wind turbines are expected to occur each year.

As was the case during the baseline studies, there were no indications that seasonal migration took place in the study area and we therefore still assume that the majority of whooper swans registered in the study were local birds. This is supported by the relatively low flight altitude observed among whooper swans.

Whooper swans are characterized by high wing loading and a low aspect ratio, resulting in rapid flight and low manoeuvrability. This means that there may also be an additional risk of collisions between this species and other structures at the test centre, e.g. guy wires and masts. This is particularly the case in situations where visibility is reduced due to adverse weather conditions, or during morning and evening flights, when light intensities are low (Larsen & Clausen 2002).

### Intermediate assessment

The results from the post-construction study support our preliminary assessment that the potential impact of the structures at the test centre on whooper swans is considered to be insignificant. However, on the basis of the regular occurrence of whooper swans in the study area, data will continue to be collected during the post-construction programme to improve the level of detail in the assessment of potential negative effects of the test centre on this population.

## Tundra swan

### General occurrence

The vast majority of tundra swans occurring in Denmark during spring and autumn migration belong to the Russian breeding population, which today comprises around 21,500 individuals following a decline since the mid-1990s (Nagy et al. 2011). In winter, most flocks migrate further south to wintering areas in England, Ireland, The Netherlands and Belgium. In November, up to 1,200 tundra swans occur in Denmark (Nagy et al. 2011), particularly in western and northern Jutland.

### Temporal and spatial patterns of occurrence in the study area

Small numbers of tundra swans were registered in the study area in October-November, which coincided with the peak migration of this species (Tab. 5). This was also the case during the baseline studies.

Table 5. Numbers of tundra swans passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 0/0 | 0/0 | 5/111 | 5/131 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |
| South | 0/0 | 0/0 | 8/183 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |
| Total | 0/0 | 0/0 | 13/294 | 5/131 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |

Most tundra swans were observed in the northern part of the study area, which was also the case during the baseline studies (Fig. 17).

Altogether, 35.8% and 57.1% of the observed individuals and flocks, respectively, of tundra swans occurred at rotor height (min. 45 - max. 222 m), whereas 64.2% and 42.9% of individuals and flocks, respectively, were below rotor height (Fig. 18).

Thus, flight altitude of tundra swans is considerably higher than the flight altitude of the related whooper swan, which was also the case during the baseline studies. This suggests that the tundra swans occurring in the study area are migrating over larger distances than the whooper swans.

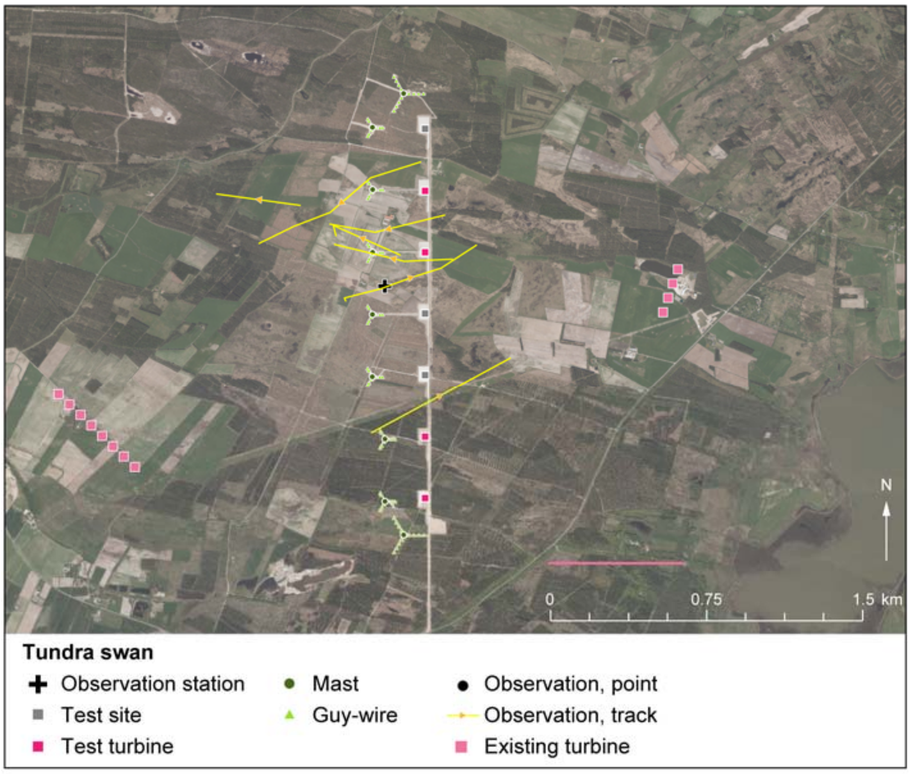



**Figure 17.** Overall flight patterns of tundra swans in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (1,281 m) from the observer within which 90% of the observation points were located.

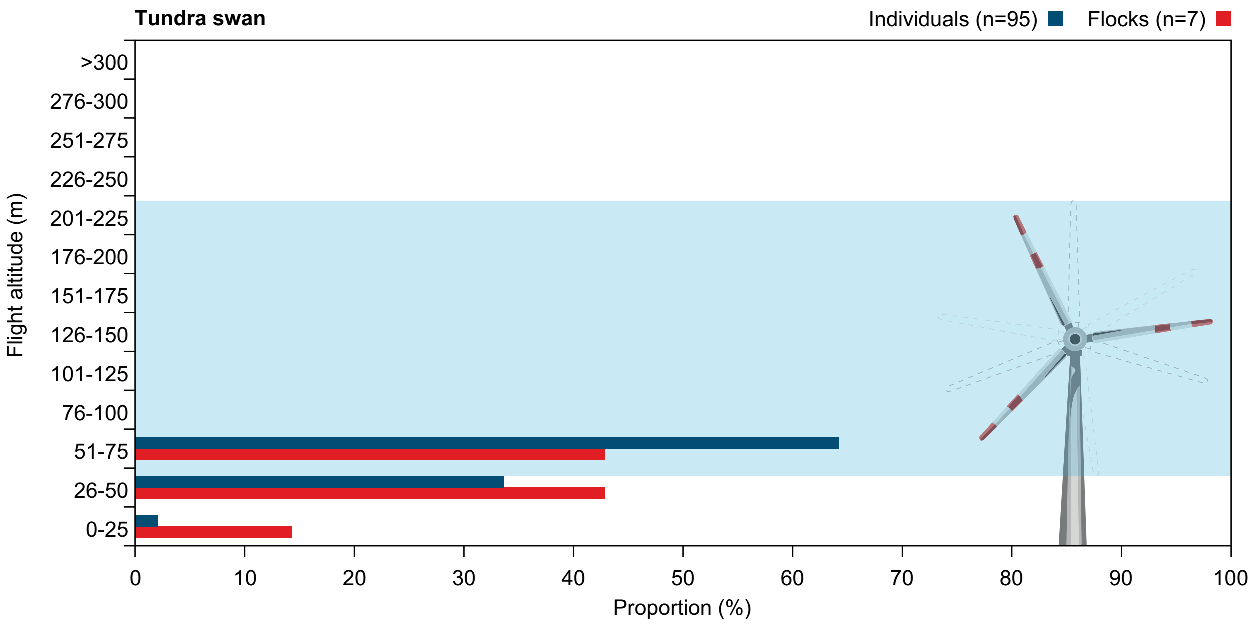



**Figure 18.** Flight altitudes of tundra swans expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

## Avoidance

When we compared flight patterns of tundra swans obtained in the baseline and the post-construction studies, there was no significant effect of 1) the distance and 2) the interaction effect between distance and the two study years (Tab. B1). The non-significant interaction effect indicates that tundra swans did not alter their flight altitude during the post-construction study compared to the baseline. The non-significant effects of distance suggest that tundra swans did not alter their flight altitude in relation to the distance to the wind turbines and other structures in general.

### Estimate of collision risk at turbines and other structures

An estimated 0.01-0.04 collisions between tundra swans and wind turbines are expected to take place each year. The estimate is lower than the estimate obtained from the baseline studies (0.42), although the baseline study covered only some of the time during which tundra swans are present in northwest Jutland. The post-construction study therefore confirmed the result of the baseline study that only a few collisions between tundra swans and wind turbines are expected to occur each year.

Tundra swan is characterized by high wing loading and a low aspect ratio, resulting in rapid flight and low manoeuvrability. Therefore there may be an associated risk of collisions between tundra swans and other structures at the test centre, e.g. guy wires and masts. This is particularly the case in situations where visibility is reduced due to adverse weather conditions, or at dusk.

### Intermediate assessment

The results from the post-construction study support our preliminary assessment that the potential impact of the structures at the test centre on tundra swans is considered to be insignificant. However, on the basis of the regular occurrence in the study area the tundra swan will continue to be included in the post-construction programme as a focal species.

## Pink-footed goose

### General occurrence

Northwest Jutland is an important wintering and staging area for the Svalbard breeding population of pink-footed goose, which in recent years has increased to approximately 76,000 individuals (Madsen et al. 2014). Up to 16,000 pink-footed geese occur in Vejlerne from September until late April (DOFbasen), where they perform daily movements between night roosts and feeding areas, and additional movements between different feeding areas during the day. The baseline study demonstrated that daily movements of pink-footed geese result in frequent passages through the study area.


**Figure 19.** A flock of pink-footed geese passing through the study area. © Henrik Haaning Nielsen.

### Temporal and spatial patterns of occurrence in the study area

Pink-footed geese (Fig. 19) occurred in the study area from September-April. Highest numbers were registered in September, October and March. Relatively few pink-footed geese were registered in April, when the departure to the breeding areas normally takes place (Tab. 6).

**Table 6.** Numbers of pink-footed geese passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 0/0 | 299/8332 | 69/1526 | 0/0 | 41/1086 | 9/254 | 0/0 | 58/1638 | 71/2030 | 0/0 |
| South | 0/0 | 957/25732 | 5462/125086 | 735/19315 | 520/14217 | 222/6264 | 164/5807 | 1072/31477 | 103/2945 | 0/0 |
| Total | 0/0 | 1256/34064 | 5531/126612 | 735/19315 | 561/15303 | 231/6518 | 164/5807 | 1130/33115 | 174/4975 | 0/0 |

Flocks of pink-footed geese were registered in most parts of the study area (Fig. 20), although more birds occurred in the southern part (Tab. 6). This pattern is similar to what was observed during the baseline studies and probably reflects the short distance to the important staging area Vejlerne situated in a southerly direction. The overall flight pattern confirms the findings from the baseline study that the pink-footed geese occurring in the study area are local birds commuting between different feeding areas and night roosts.

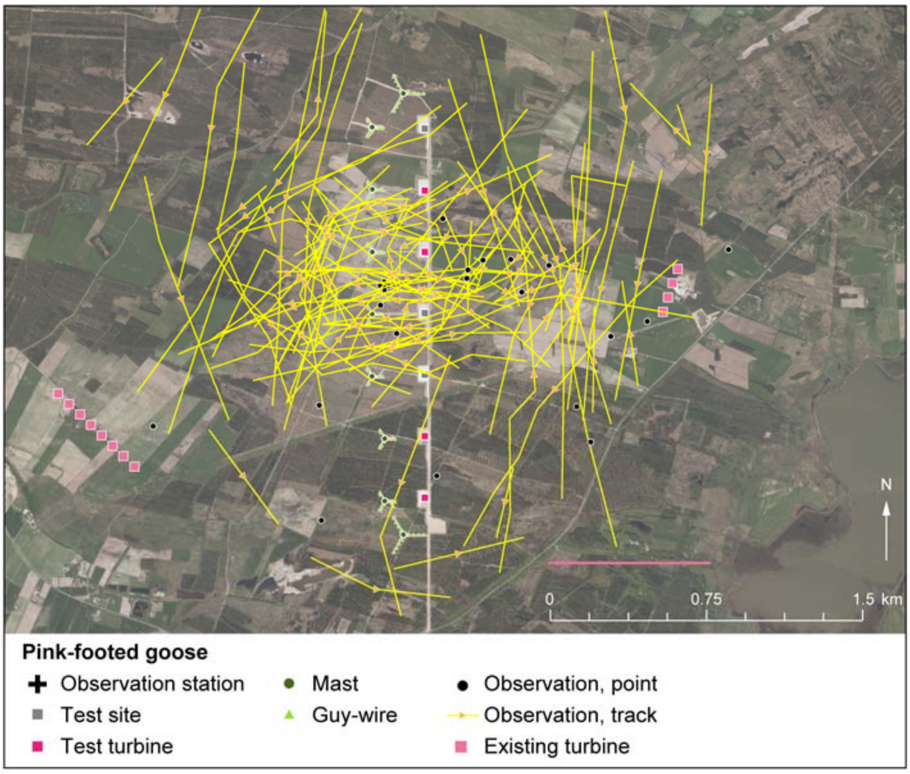



**Figure 20.** Overall flight patterns of pink-footed geese in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (1,537 m) from the observer within which 90% of the observation points were located.

Altogether, 76.7% and 78.9% of the observed individuals and flocks, respectively, of pink-footed geese occurred at rotor height (min. 45 - max. 222 m), whereas 23.3% and 22.1% of individuals and flocks, respectively, were outside rotor height (Fig. 21).

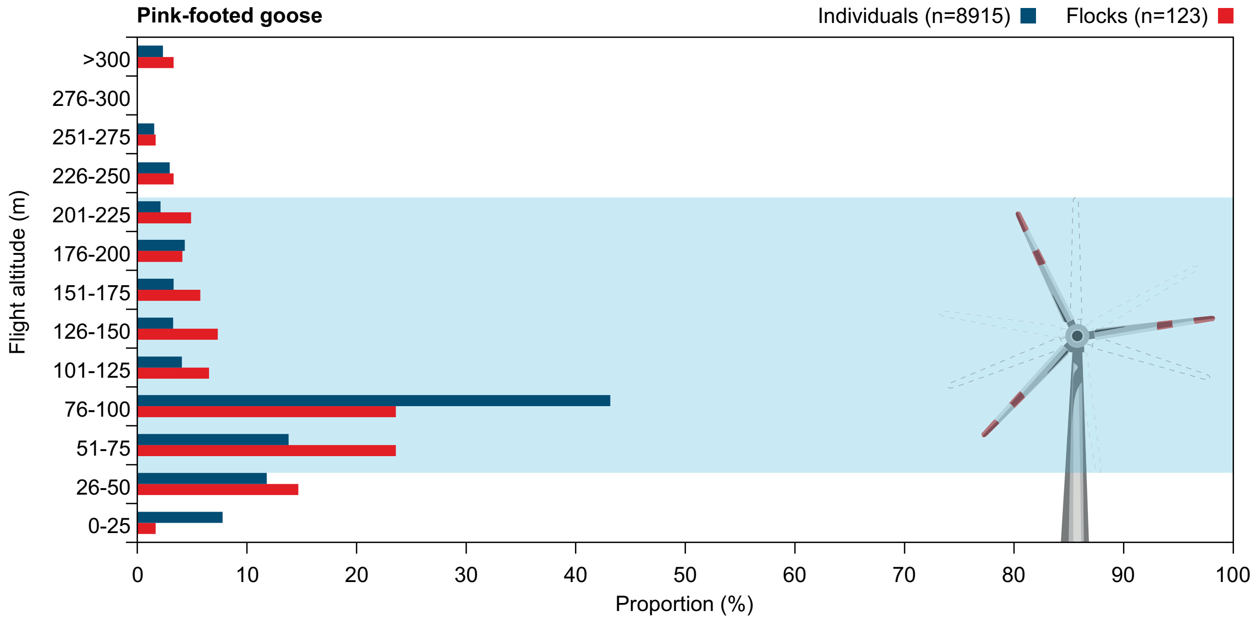



**Figure 21.** Flight altitudes of pink-footed geese expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

### Avoidance

Our comparison of flight patterns of pink-footed geese obtained in the baseline and the post-construction studies showed that pink-footed geese did not alter their flight altitude in relation to the distance in response to the to the wind turbines and other structures (Tab. B1). However, the significant effect of distance in general indicated that pink footed geese were observed at higher altitudes with increasing distance to the wind turbines (Tab. B1, B3). This could be an observational bias as flocks further away may be more easily detected at higher altitudes. The parameter estimate suggests that altitude increased with distance from the wind turbine sites. However, this estimate is not significant (Tab B4).

### Estimate of collision risk at turbines and other structures

An estimated 10-23 collisions between pink-footed geese and wind turbines are expected to take place each year. This is comparable to the estimate obtained from the baseline studies (21-46), although the baseline study covered only some of the time during which pink-footed geese are present in northwest Jutland. The post-construction study therefore confirmed the result of the baseline study that only a few collisions between pink-footed geese and wind turbines are expected to occur each year.

The baseline collision estimate was based on an observed avoidance rate of 97.75%, which was obtained from a comparable study at nearby Klim Fjordholme and a theoretical avoidance rate of 99%, which is closer to the estimates found in other goose studies (Kahlert et al. 2010). It therefore seems that avoidance exhibited by pink-footed geese around the test centre is closer to the 99% found in other studies.

It should be noted that observation days were restricted to periods with mainly favourable weather conditions, when flight activity is expected to be higher than during adverse weather conditions. It should also be noted that weather conditions (visibility and wind speed) and other factors may affect flight altitudes and, hence, the number of birds passing the area at rotor height.

It should also be noted that pink-footed geese are characterized by high wing loading and a low aspect ratio, resulting in rapid flight and low manoeuvrability, means that there may also be an additional risk of collisions between this species and other structures at the test centre, e.g. guy wires and masts.

#### Intermediate assessment

The estimated collision frequency corresponds to 0.01-0.02% of the total Svalbard breeding population, which amounts to 76,000 individuals (Madsen et al. 2014), and to 0.05-0.10% of the maximum number of individuals (ca. 16,000) observed in northwest Jutland in recent years. No attempt was made to assess the potential impact on local populations, since the flocks present in northwest Jutland must be considered to belong to the same regional population, which most likely is a mixture of birds utilizing the local SPAs to a lesser or greater extent.

The results from the post-construction study support our preliminary assessment that the potential impact of the structures at the test centre on pink-footed geese is considered to be insignificant. However, on the basis of the regular occurrence in the study area the pink-footed goose will continue to be included in the post-construction programme as a focal species.

### Taiga bean goose

#### General occurrence

The bean geese that occur in northwest Jutland belong to the subspecies *A. f. fabalis* also known as the taiga bean goose. The flocks observed in northwest Jutland during migration and winter belong to the small sub-population breeding in central Sweden. With the onset of cold weather and snow, and there is some evidence of exchange between these flocks and those that winter in eastern England. The national conservation status for the sub-population is at present uncertain (Pihl et al. 2006). Therefore, the sub-population, which numbers probably less than 2,000 individuals, was protected from hunting in Jutland by Government Order from 2004 onwards.

#### Temporal and spatial patterns of occurrence in the study area

Taiga bean geese occurred in the study area September-February. The highest number of individuals was registered in December (Tab. 7). In contrast to the baseline studies no taiga bean geese were observed in early autumn.

**Table 7.** Numbers of taiga bean geese passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 0/0 | 0/0 | 0/0 | 0/0 | 22/583 | 0/0 | 4/137 | 0/0 | 0/0 | 0/0 |
| South | 0/0 | 0/0 | 0/0 | 0/0 | 45/1230 | 2/56 | 0/0 | 0/0 | 0/0 | 0/0 |
| Total | 0/0 | 0/0 | 0/0 | 0/0 | 67/1813 | 2/56 | 4/137 | 0/0 | 0/0 | 0/0 |

Most of the taiga bean geese were tracked near the observation station in the central, open part of the study area. The majority of flocks moved in an east to west direction (Fig. 22), which indicates that the bean geese observed in the study area were autumn staging and to a lesser extent wintering flocks commuting between roosts and feeding areas. The flight pattern reflects that on some occasions taiga bean geese were feeding on fields in the eastern part of the study area. Apart from this, the overall flight pattern is similar to what was observed during the baseline studies.

Altogether, 27.5% and 40.3% of the observed individuals and flocks, respectively, of taiga bean geese occurred at rotor height (min. 45 - max. 222 m), whereas 72.5% and 59.7% of individuals and flocks, respectively, were below rotor height (Fig. 23).

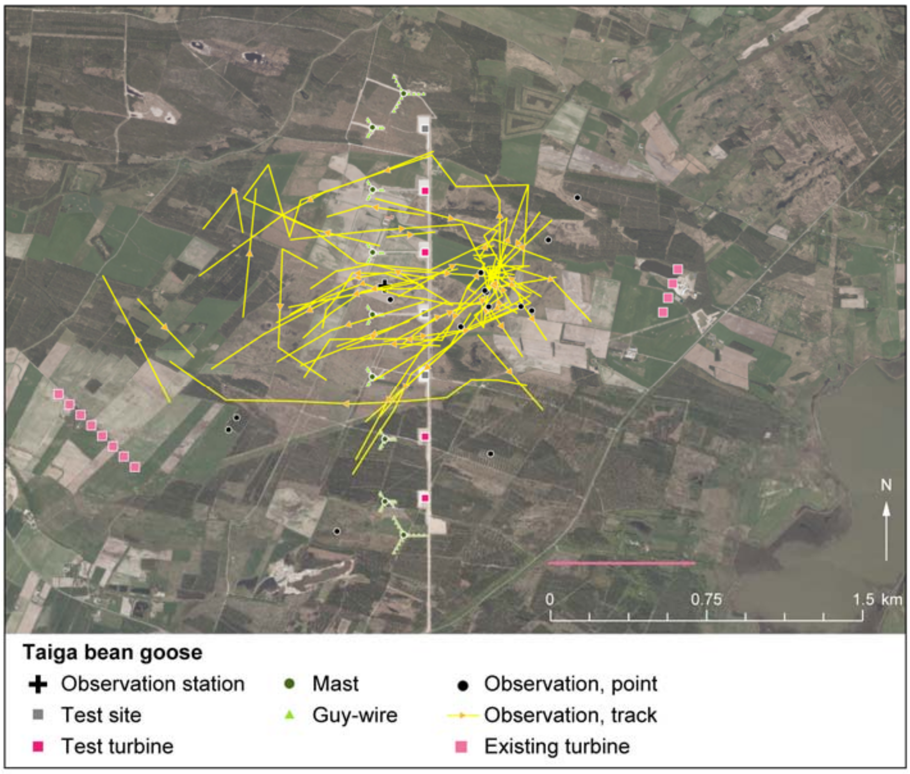



**Figure 22.** Overall flight patterns of taiga bean geese in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (1,382 m) from the observer within which 90% of the observation points were located.

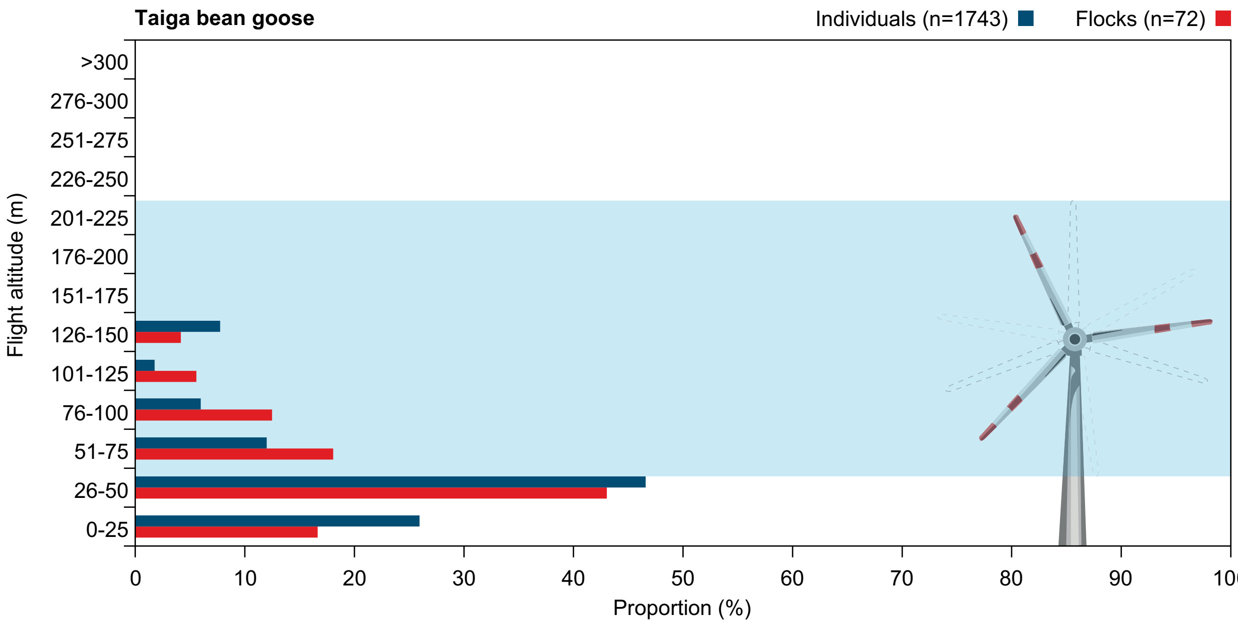



**Figure 23.** Flight altitudes of taiga bean geese expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

### Avoidance

The interaction effect between distance and baseline versus post construction indicates that the taiga bean geese have changed their altitude in response to the wind turbines (Tab. B1). The statistical analysis showed that the slope estimates were negative for both baseline and post-construction (Tab. B2), which suggest that bean geese generally increased their altitude in the wind turbine area in both situations. However, the increase in altitude was larger during the post-construction study as indicated by the steeper slope and the significant interaction effect (App. B2). It should be noted that the slope during the pre-construction is not significant, which means that there was no significant effect of distance to the study site during the pre-construction studies.

### Estimate of collision risk at turbines and other structures

Less than one (0.04-0.10) collision per year between taiga bean geese and wind turbines is expected.

The data collected during both the baseline and post-construction programmes is not sufficient to describe diurnal activity patterns of taiga bean geese. However, we assume that the pattern resembles what has been found for pink-footed geese at nearby Klim Fjordholme (Kahlert et al. 2012b), which means that taiga bean geese may be most active around sunrise and sunset. This observation combined with the fact that that bean geese are characterized by high wing loading and a low aspect ratio, resulting in rapid flight and low manoeuvrability, indicates that there may also be an associated risk of collisions between this species and other structures at the test centre, e.g. guy wires and masts. This is particularly the case in situations, when visibility is reduced due to adverse weather conditions.

In contrast to the baseline study, the observation period of the post-construction period covered the entire time period during which taiga bean geese are present in northwest Jutland.

The post-construction study therefore confirmed the result of the baseline study that only a few collisions between taiga bean geese and wind turbines are expected to occur each year.

### Intermediate assessment

The results from the post-construction study support our preliminary assessment that the potential impact of the structures at the test centre on the subpopulation of bean geese is considered to be insignificant. However, on the basis of the regular occurrence in the study area and the conservation status for this sub-population, the taiga bean geese will continue to be included in the post-construction programme as a focal species.

## Greylag goose

### General occurrence

The Danish greylag geese belong to the northwest European breeding population, which winters in the Netherlands and Spain. Since the 1960s this population has increased dramatically to more than 610,000 individuals (Fox et al. 2010). Nearby Vejlerne is the most important breeding site with more than 1,000 pairs (Pihl et al. 2006). In autumn, greylag geese from Denmark and Norway stage in west Jutland prior to the departure to the wintering grounds further south. In mild winters an increasing number of greylag geese stay in the country.

### Temporal and spatial patterns of occurrence in the study area

Greylag geese were observed throughout the study period. The highest numbers were observed in August-September, which coincided with the peak migration period for this species. Relatively few greylag geese were observed during mid-winter and in spring (Tab. 8). This was also the case during the baseline studies.

Table 8. Numbers of graylag geese passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 52/1505 | 127/3539 | 65/1437 | 0/0 | 0/0 | 0/0 | 21/720 | 141/3981 | 12/343 | 27/790 |
| South | 7568/215650 | 2795/75151 | 158/3618 | 48/1261 | 141/3855 | 16/451 | 22/779 | 41/1204 | 37/1058 | 2/60 |
| Total | 7620/217155 | 2922/78690 | 223/5055 | 48/1261 | 141/3855 | 16/451 | 43/1499 | 182/5185 | 49/1401 | 29/850 |

Greylag geese were observed throughout the study area. In contrast to the baseline studies, where the majority of flocks moved in an east-west direction, there was no apparent overall flight pattern (Fig. 24).

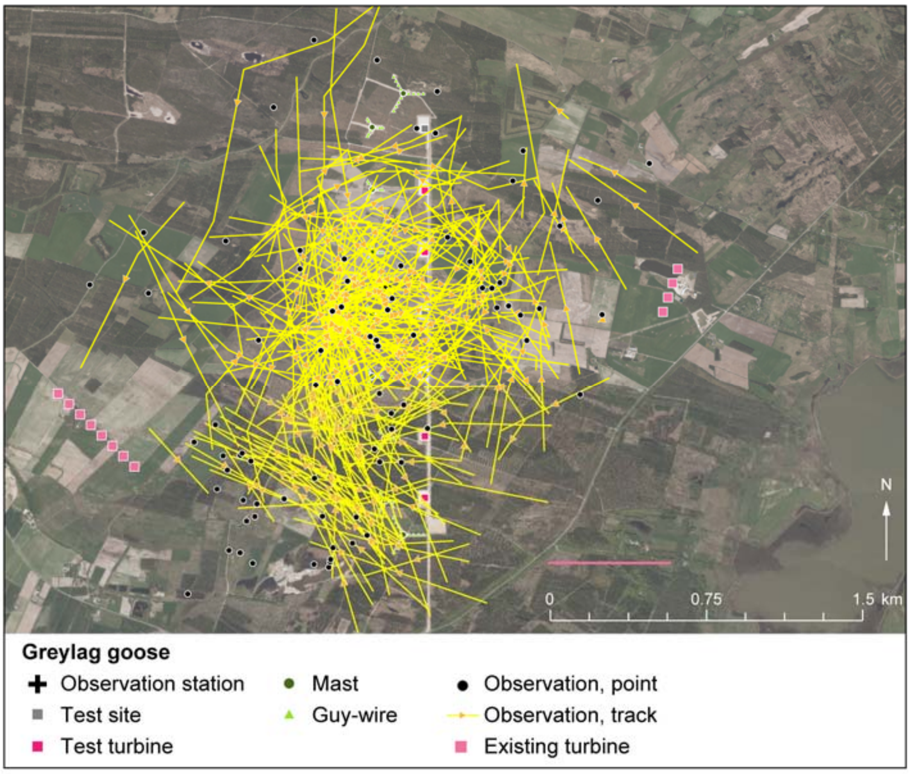



**Figure 24.** Overall flight patterns of graylag geese in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (1,148 m) from the observer within which 90% of the observation points were located.

Altogether, 64.5% and 73.2% of the observed individuals and flocks, respectively, of greylag geese occurred at rotor height (min. 45 - max. 222 m), whereas 35.5% and 26.8% of individuals and flocks, respectively, were outside rotor height (Fig. 25).

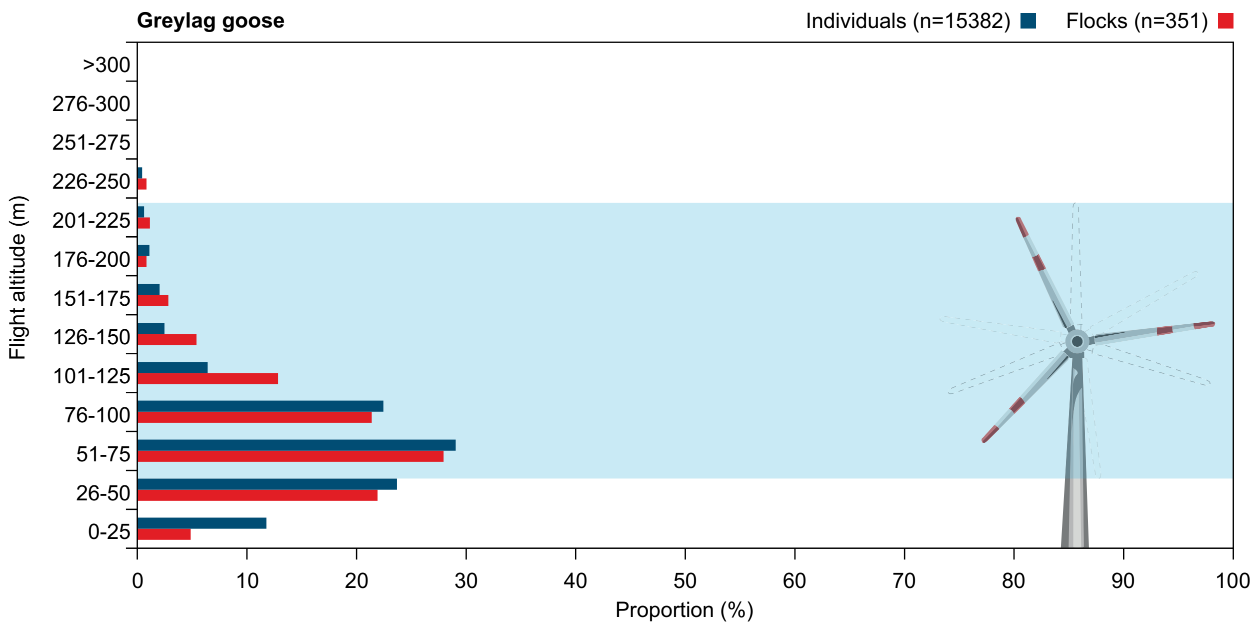



**Figure 25.** Flight altitudes of graylag geese expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

### Avoidance

When we compared flight altitude of greylag geese obtained in the baseline and the post-construction studies, there was no significant effect of 1) the distance and 2) the interaction effect between distance and the two study years (Tab. B1). The non-significant interaction effect indicates that greylag geese did not alter their flight altitude in relation to distance during the post-construction study compared to the baseline. The non-significant effects of distance suggest that greylag geese did not alter their flight altitude in relation to the distance to the wind turbines and other structures in general. Generally, the flight altitude was significantly higher during the baseline study.

### Estimate of collision risk at turbines and other structures

An estimated 23-52 collisions between greylag geese and wind turbines are expected to take place each year. The estimate is higher than the estimate obtained from the baseline studies (3-6), which only covered some of the time during which greylag geese are present in northwest Jutland. In particular, it should be noted that during the baseline study no data were collected in August, where numbers peaked in the post-construction study, and that in general greylag goose numbers were higher during the post-construction study than during the baseline study.

The tendency for greylag geese to be more active around dawn in combination with the fact that this species is characterized by high wing loading and a low aspect ratio, resulting in rapid flight and low manoeuvrability, indicates that there may also be an addtional risk of collisions between greylag geese and other structures at the test centre, e.g. guy wires and masts. This is particularly the case in situations where visibility is reduced due to adverse weather conditions.

### Intermediate assessment

The results from the post-construction study support our preliminary assessment that the potential impact of the structures at the test centre on the population of greylag geese is considered to be insignificant. Although the calculated number of collisions must be regarded as a crude estimate, the potential impact of the combined structures at the test centre on greylag geese is still considered to be insignificant.

However, on the basis of the regular occurrence of both breeding and autumn staging individuals in northwest Jutland, and the increase in numbers in the study area, data on greylag geese will continue to be collected during the post-construction programme to improve the level of detail in the assessment of potential negative effects of the test centre on this population.

## Light-bellied brent goose

### General occurrence

Denmark is the most important wintering site for The East Atlantic (Svalbard) flyway population of the light-bellied brent goose, which breeds in the eastern and northern parts of Svalbard and to a lesser extent in northeast Greenland. The whole population assembles at a few spring staging sites in northwest Denmark prior to departure to the breeding grounds.

### Temporal and spatial patterns of occurrence in the study area

In the morning of May 27, three flocks of 105, 80 and 35 light-bellied brent geese were observed migrating in the vicinity of the study area. In the morning of May 29 another flock of 55 individuals was observed. The flocks were initially spotted in a southerly or westerly direction and they all passed the test centre to the west. Three of the flocks followed a northerly direction. The observations coincided with the normal northbound mass departure (Clausen et al. 2003), which was also the case during the baseline studies, where 279 individuals were observed on the northward migration.

In one case, the distance to the observation station as the flocks passed the test centre was measured to 4.0 km, whereas the distance to the remainder of the flocks was estimated at 1.5, >3 km and >5 km. It was not possible to track the migration route of the flocks due to both the distance and relatively low visibility.

The migration routes of some of the six flocks observed during the baseline studies were closer to the test centre compared to the four flocks observed during the post-construction studies. This may be a result of avoidance, although the sample size is too small to confirm this.

Fox et al. (2010) estimated the East-Atlantic flyway population of light-bellied brent geese to 7,600 individuals. However, based on a more recent expert judgment, the population may have declined to 6,000 individuals in winter 2011/12 (P. Clausen, pers. comm.). This means that the 275 individuals passing the study area correspond to 3.6-4.6% of the total population.

The national conservation status for the small population of light-bellied brent goose is preliminarily assessed as unfavourable-increasing (Pihl et al. 2006). Therefore the population must be considered to be highly sensitive to any additional mortality.

**Intermediate assessment**
The amount of data collected during the baseline and post-construction studies is not sufficient to perform meaningful statistical analyses to estimate collision numbers for this species. However, although the amount of data is limited, the observations indicate that the risk of collisions between turbines at the test centre and light-bellied brent geese is very low. We therefore consider the potential impact of the combined structures at the test centre on the population of light-bellied brent geese to be small. It should be noted that given the small size of this population even a smaller number of collisions may have a negative impact on the species.

Even though both the baseline and the post-construction studies have confirmed that the overall migration of light-bellied brent geese is expected to be in a northerly direction, which is parallel to the north-south orientation of the test centre, different wind directions may change the migration path and, hence, the risk of collisions. On this basis, the species will continue to be included in the post-construction study as a focal species given its high conservation status.

## White-tailed eagle

### General occurrence
The breeding population size of Danish white-tailed eagles is around 50 pairs, which mainly occur on Zealand, Lolland and Falster, although in recent years the population has expanded towards the western part of the country. In winter, white-tailed eagles from Norway, Sweden, Finland and western Russia visit Denmark. White-tailed eagle is now becoming established as a breeding bird in northwest Jutland and an increasing number of immature individuals occur in nearby Vejlerne outside the breeding season.

### Temporal and spatial patterns of occurrence in the study area
White-tailed eagle (Fig. 26) occurred in the study area from August-May, with most observations in autumn (Tab. 9). Individuals of all age classes were observed, whereas two white-tailed eagles, which were observed together on several occasions, represent a breeding pair, which has become established in the vicinity of the test centre. During the baseline studies only one white-tailed eagle was registered and therefore the number of observations made during the post-construction study represent a marked increase in the occurrence of this species.

**Table 9.** Numbers of white-tailed eagles passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 0/0 | 4/111 | 1/22 | 3/79 | 0/0 | 0/0 | 0/0 | 2/56 | 4/114 | 0/0 |
| South | 0/0 | 6/161 | 7/160 | 6/158 | 1/27 | 3/85 | 1/35 | 1/29 | 0/0 | 1/30 |
| Total | 0/0 | 10/272 | 8/182 | 9/237 | 1/27 | 3/85 | 1/35 | 3/85 | 4/114 | 1/30 |

White-tailed eagles were observed throughout the study area (Fig. 27). There was no clear flight pattern, although most of the observations were made in the southern part of the study area. This may reflect the short distance to Vejlerne, which is situated in a southerly direction, and probably represent an important feeding area to the white-tailed eagles occurring in the area.

**Figure 26.** A white-tailed eagle soaring in the study area. © Jørgen Peter Kjeldsen.

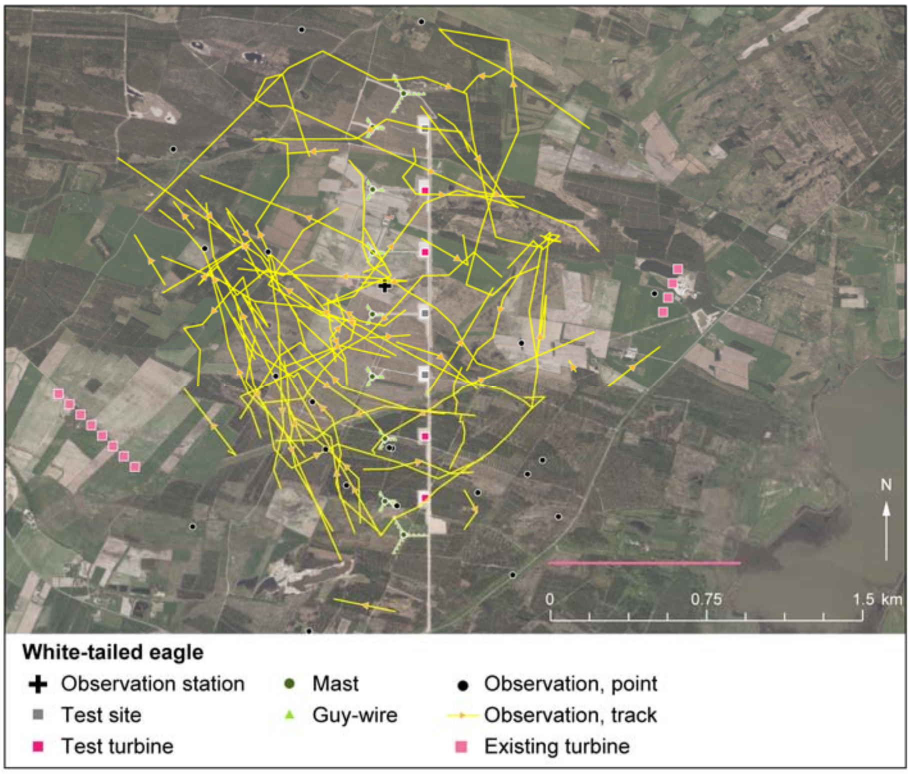



**Figure 27.** Overall flight patterns of white-tailed eagles in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (1,834 m) from the observer within which 90% of the observation points were located.

Altogether, 47,5% and 45.3% of the observed individuals and flocks, respectively, of white-tailed eagles occurred at rotor height (45-175 m), whereas 52.5% and 54.7% of individuals and flocks, respectively, were outside rotor height (Fig. 28).

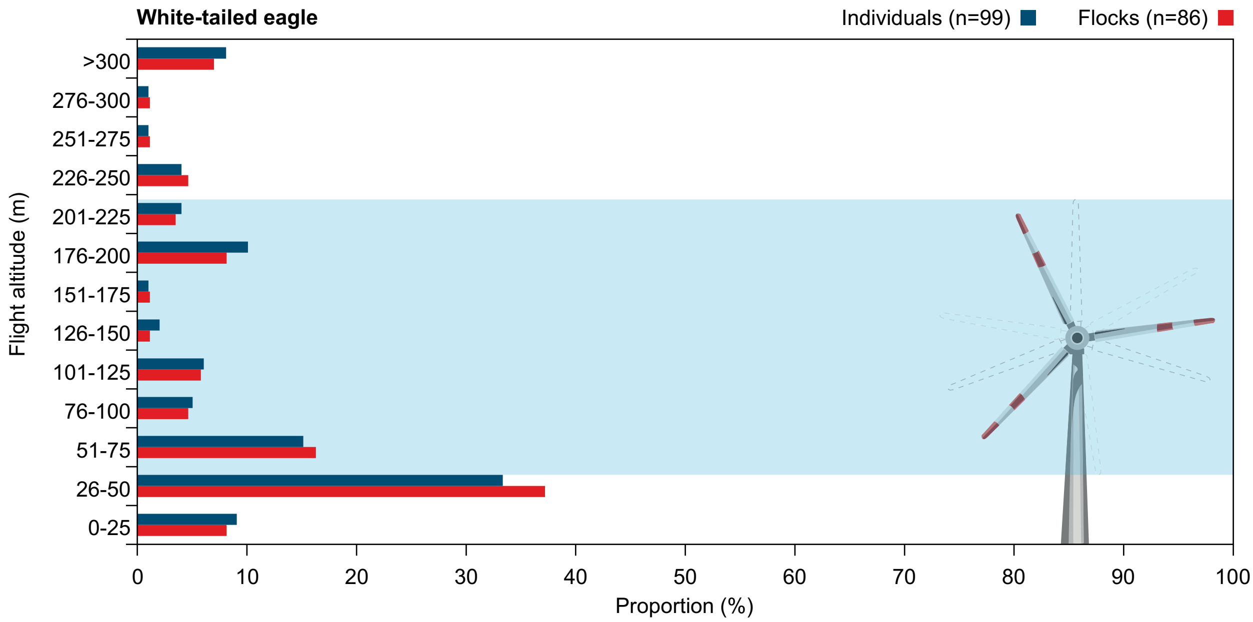



**Figure 28.** Flight altitudes of white-tailed eagles expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

### Estimate of collision risk at turbines and other structures

Less than one (0.03-0.08) collision between white-tailed eagle and wind turbines is expected to take place each year. No collision estimate was calculated on the basis of the baseline study.

The post-construction study showed that the study area is regularly used by white-tailed eagles. Even though white-tailed eagles were observed more often during the post-construction studies than during the baseline studies, only very few collisions are expected. This is primarily a result of the low flight height of this species. We therefore expect the risk of collisions with turbines and other structures at the test centre to be of minor importance, although low visibility may increase the risk of collisions.

### Intermediate assessment

White-tailed eagle is a scarce breeding bird in Denmark, although the population has increased in recent years. The relatively small size of the population means that in the case of a collision between a breeding bird and a turbine or mast, a relatively large proportion of the Danish and the regional population would be affected. However, the post-construction study showed that only a small number of collisions are expected.

The recent establishment of a breeding population of white-tailed eagles in northwest Jutland may potentially increase the occurrence of the species in the study area and, hence, the risk of negative impacts on the population. The presence of white-tailed eagles will therefore be followed closely in the post-construction programme to obtain more data to support the final assessment of the potential impact of the test centre on this species.

## Peregrine falcon

### General occurrence

Peregrine falcon is a rare breeding bird in Denmark and most of the individuals observed in the country originate from northern Scandinavia. Numbers in Denmark peak during spring (April) and autumn migration (September-October).

### Temporal and spatial patterns of occurrence in the study area

Small numbers of peregrine falcon was observed from September-December and April-May. Like during the baseline studies, the observations were made near the observation station in the central part of the study area. The observations coincided with the autumn and spring migration periods for this species (Tab. 10, Fig. 29).

The few peregrine falcons observed in the study area, were therefore most likely autumn and spring staging individuals of unknown origin.

**Table 10.** Numbers of peregrine falcons passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |
| South | 0/0 | 1/27 | 7/160 | 2/53 | 1/27 | 0/0 | 0/0 | 0/0 | 1/29 | 1/30 |
| Total | 0/0 | 1/27 | 7/160 | 2/53 | 1/27 | 0/0 | 0/0 | 0/0 | 1/29 | 1/30 |

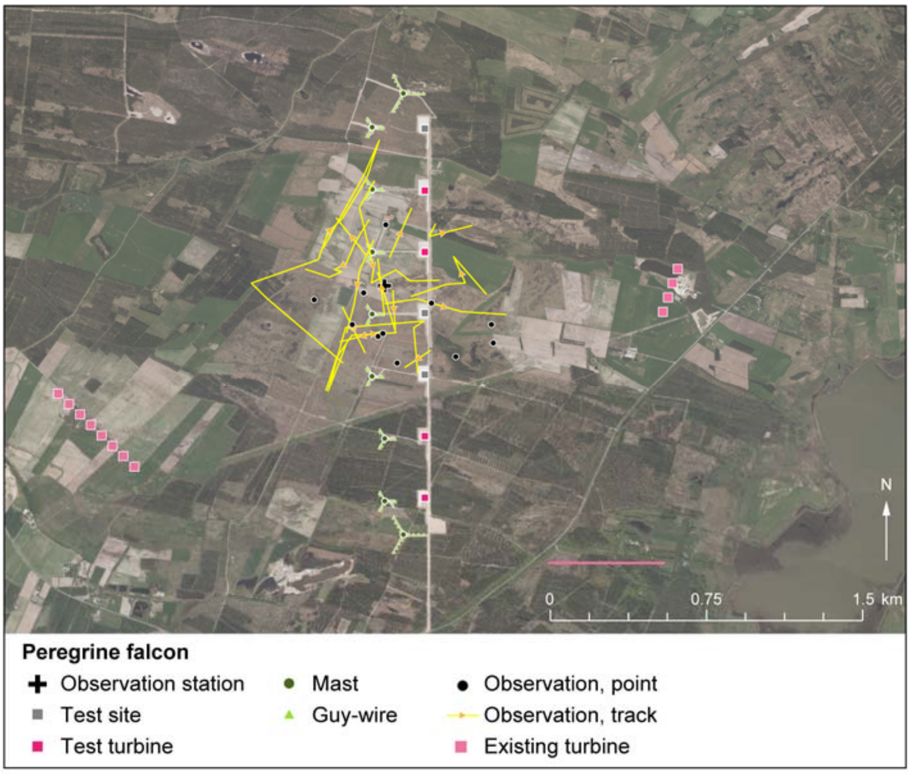



**Figure 29.** Overall flight patterns of peregrine falcons in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (1,100 m) from the observer within which 90% of the observation points were located.

Altogether, 13.3% and 14.3% of the observed individuals and flocks, respectively, of peregrine falcons occurred at rotor height (min. 45 - max. 222 m), whereas 86.7% and 85.7% of the remainder of individuals and flocks, respectively, were below rotor height (Fig. 30).

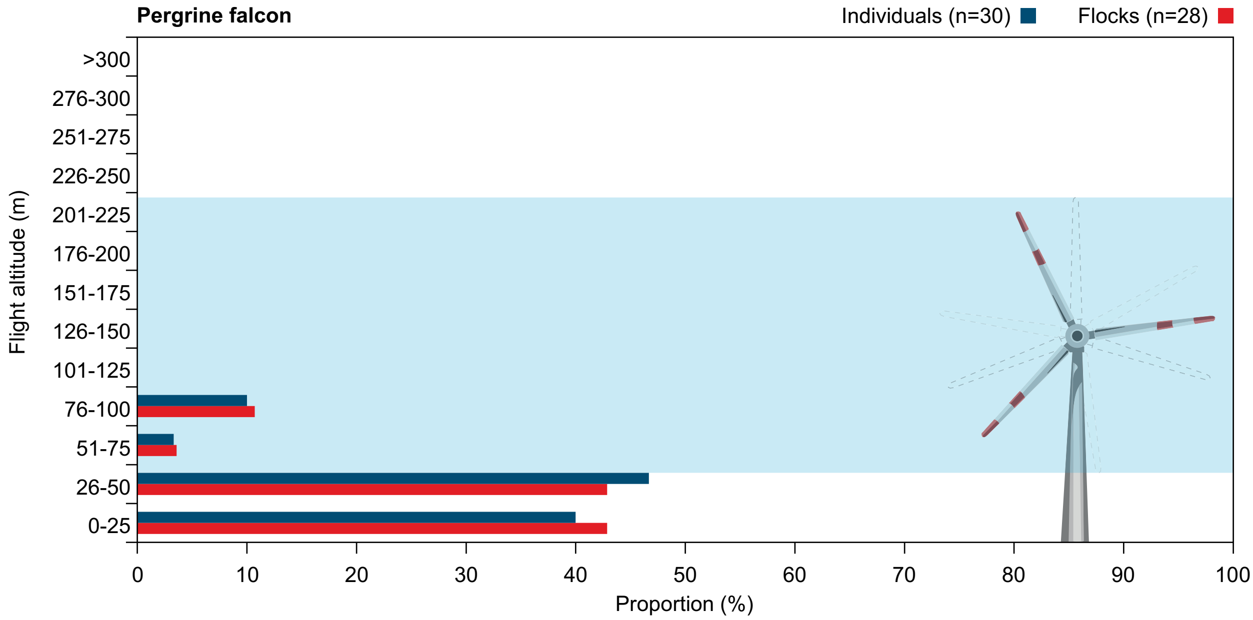



**Figure 30.** Flight altitudes of peregrine falcons expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

### Avoidance

The significant interaction between distance and baseline versus post-construction indicate that the flight altitude in relation to distance to the study area differ between baseline and post construction (Tab. B1). The slope estimate was positive for the baseline and negative for the post-construction study (Tab. B2). The negative slope estimate suggests that peregrine falcons increased their flight altitude when approaching the wind turbines. Note that the slope for the pre-construction study is not significant, which means that there was no significant effect of distance to the area in this situation.

### Estimate of collision risk at turbines and other structures

Less than one (0.01-0.02) collision between peregrine falcons and wind turbines is expected to take place each year. This estimate is similar to the result obtained during the baseline studies (0.01 collision per year), although this covered only part of the year.

The post-construction study confirmed that the study area is only used occasionally by peregrine falcons and we therefore expect the risk of collisions with turbines and other structures at the test centre to be of minor importance, although low visibility may increase the risk of collisions. It should be noted that on some occasions peregrine falcons were observed perching on met masts, which may potentially increase the risk of collisions.

### Intermediate assessment

The Danish breeding population is small (around 15 pairs) and vulnerable to extra mortality. Therefore, in the case of a collision between a breeding bird and a turbine or other structures, a relatively large proportion of the Danish population would be affected. This also applies to the scarce occurrences of non-breeding individuals in northwest Jutland. However, considering the absence of breeding pairs in north Jutland and the continued scarce occurrence of staging or overwintering individuals in the study area, we still consider the potential negative effects on peregrine falcons to be close to negligible.

## Kestrel

### General occurrence

Kestrel is a common breeding species throughout the country. In winter, some of the population may leave Denmark, whereas during the migration periods kestrels from Scandinavia pass through the country.

### Temporal and spatial patterns of occurrence in the study area

Kestrels occurred in the study area from August-January and April-May. No kestrels were observed in February-March, which may be a result of a cold spell in late January causing birds to migrate southwards. Peak numbers were observed in August-September and April, which coincided with the migration periods for the species (Tab. 11).

**Table 11.** Numbers of kestrels passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 32/926 | 9/251 | 1/22 | 1/26 | 1/26 | 4/113 | 0/0 | 0/0 | 8/229 | 1/29 |
| South | 28/798 | 21/565 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 6/172 | 1/30 |
| Total | 60/1724 | 30/816 | 1/22 | 1/26 | 1/26 | 4/113 | 0/0 | 0/0 | 14/401 | 2/59 |

Most kestrels were observed near the central observation station. They were probably a mixture of local and staging individuals commuting between roosts and different feeding areas (Fig. 31).


**Figure 31.** Overall flight patterns of kestrels in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (930 m) from the observer within which 90% of the observation points were located.

Altogether, 9.2% and 9.7% of the observed individuals and flocks, respectively, of kestrels occurred at rotor height (min. 45 - max. 222 m), whereas 90.8% and 90.3% of individuals and flocks, respectively, were outside rotor height (Fig. 32).

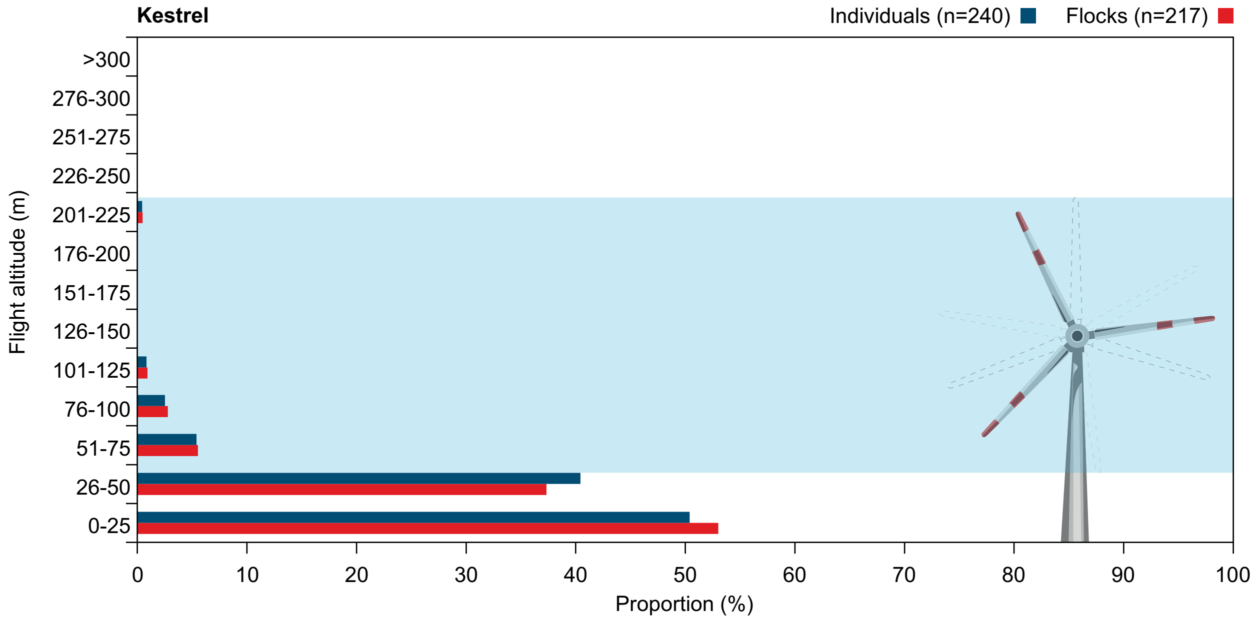



**Figure 32.** Flight altitudes of kestrels expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

### Avoidance

When we compared flight patterns of kestrels obtained in the baseline and the post-construction studies, there was no significant effect of the interaction effect between distance and the two study years (Tab. B1). The non-significant interaction effect indicates that kestrels did not alter their flight altitude in relation to distance during the post-construction study compared to the baseline. Generally, kestrels seemed to increase their flight altitude with increasing distance to the study area (Tab. B4).

### Estimate of collision risk at turbines and other structures

Less than one (0.1-0.2) collision between kestrels and wind turbines is expected to take place each year. This estimate is similar to the result obtained during the baseline studies (not presented in the baseline report), although this covered only part of the year.

The post-construction study therefore confirmed that the study area is regularly used by kestrels, which may potentially be breeding in the vicinity or in the study area. Even though more kestrels were observed during the post-construction studies than during the baseline studies, only very few collisions are expected. This is primarily a result of the low flight height of this species. We therefore expect the risk of collisions with turbines and other structures at the test centre to be of minor importance, although low visibility may increase the risk of collisions.

### Intermediate assessment

The results from the post-construction study support our preliminary assessment that the potential impact of the structures at the test centre on kestrels is considered insignificant.

## Marsh harrier

### General occurrence

Marsh harrier is a common breeding bird in Denmark. Numbers in Denmark peak during spring (April) and autumn migration (late August-early September). In winter, the birds leave the country.

### Temporal and spatial patterns of occurrence in the study area

Marsh harrier was observed from August-September and from April-May. Most observations were made in May (Tab. 12) close to the observation station in the central part of the study area (Fig. 33). This was also the case during the baseline studies and this pattern probably reflects that in most cases flight altitude of marsh harriers was low making it difficult to detect individuals at larger distances. Therefore more individuals may have occurred in other parts of the study area. The birds occurring in the study area were probably both migrants and local breeders from nearby wetlands, i.e. Vejlerne.

**Table 12.** Numbers of marsh harriers passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 3/87 | 1/28 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 4/114 | 24/702 |
| South | 5/142 | 1/27 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 3/86 | 5/151 |
| Total | 8/229 | 2/55 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 7/200 | 29/853 |

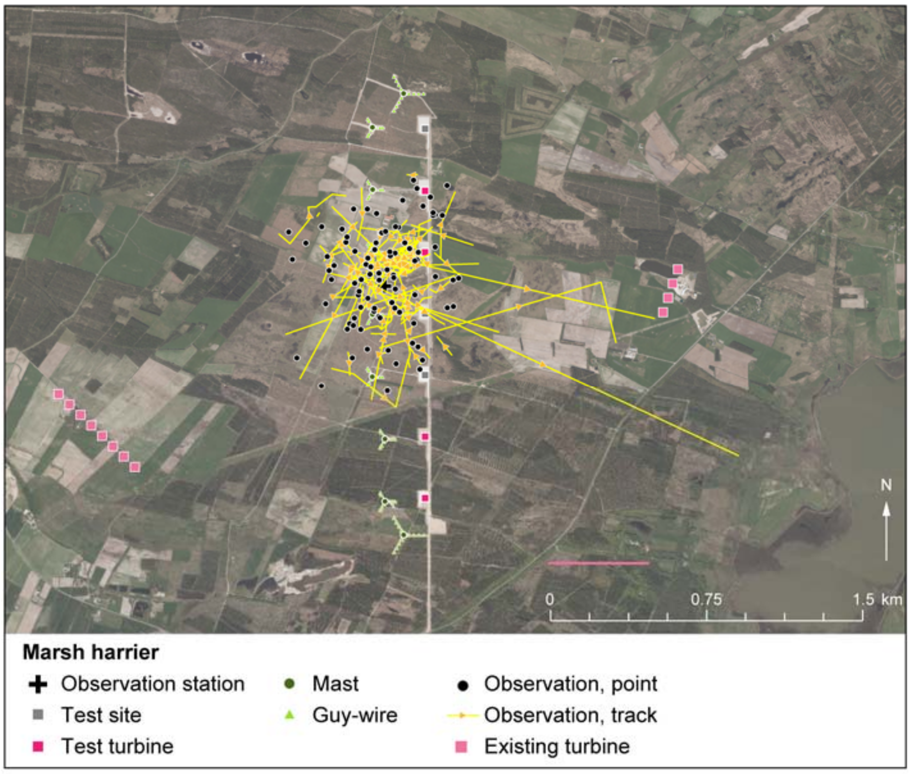
The occurrence of marsh harriers in the study area represent a marked increase compared to the number of observations made during the baseline studies. The reason for this difference remains unclear, although some of the observations may represent repeated observations of local breeders.

Altogether, 31.9% and 31.9% of the observed individuals and flocks, respectively, of marsh harriers occurred at rotor height (min. 45 - max. 222 m), whereas 68.1% and 68.1% of individuals and flocks, respectively, were outside rotor height (Fig. 34).

### Avoidance

When we compared flight patterns of marsh harrier obtained in the baseline and the post-construction studies, there was no significant effect of 1) the distance and 2) the interaction effect between distance and the two study years (Tab. B1). The non-significant interaction effect indicates that marsh harriers did not alter their flight altitude in relation to distance during the post-construction study compared to the baseline. The non-significant effects of distance suggest that marsh harriers did not alter their flight altitude in relation to the distance to the wind turbines and other structures in general.

**Figure 33.** Overall flight patterns of marsh harriers in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (956 m) from the observer within which 90% of the observation points were located.



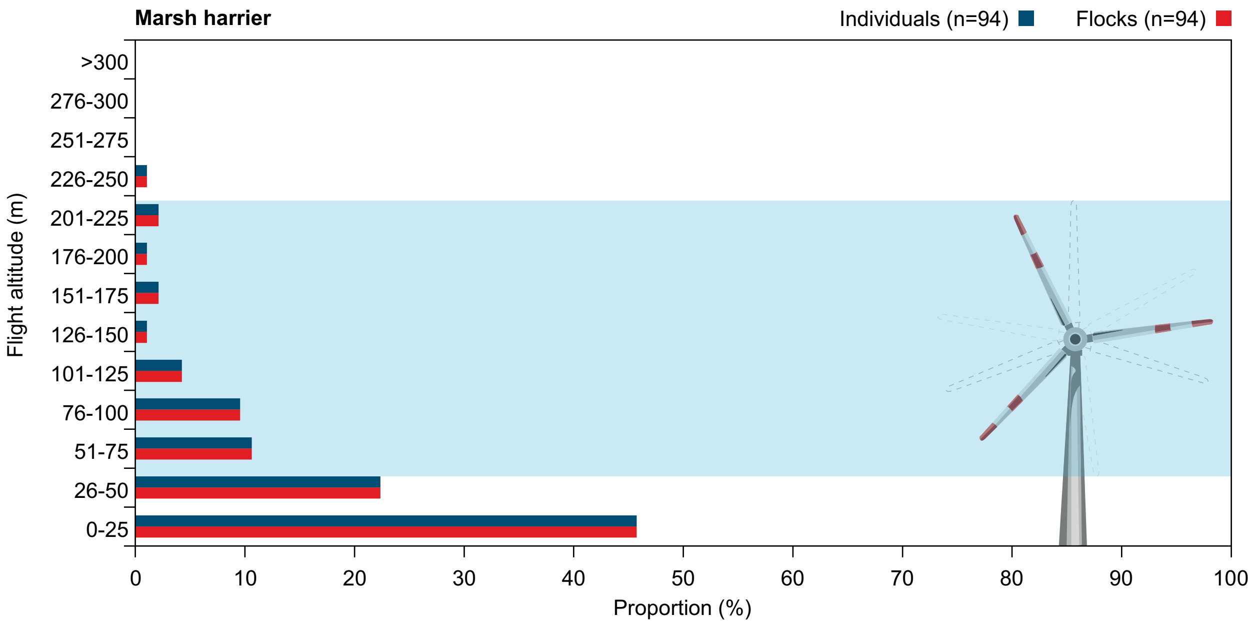




**Figure 34.** Flight altitudes of marsh harriers expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

**Estimate of collision risk at turbines and other structures**

An estimated 0.12-0.20 collisions between marsh harriers and wind turbines are expected to take place each year. This estimate is similar to the result obtained during the baseline studies (not reported in the baseline report), although this covered only part of the year.

The post-construction study showed that the study area is regularly used by marsh harriers, which may potentially be breeding in the vicinity or in the study area. Even though more marsh harriers were observed in the study area than during the baseline studies, only very few collisions are expected. This is primarily a result of the low flight height of this species. We therefore expect the risk of collisions with turbines and other structures at the test centre to be of minor importance, although low visibility may increase the risk of collisions.

#### Intermediate assessment

Although the size of the regional population in northwest Jutland remains unknown and the calculated number of collisions must be regarded as a crude estimate, the potential impact of the combined structures at test centre on the national and regional populations of marsh harriers is considered insignificant.

### Hen harrier

#### General occurrence

Hen harrier is an extremely rare breeding bird in Denmark and most of the individuals observed in the country are migrants originating from Northern Scandinavia. Numbers in Denmark peak during spring (April) and autumn migration (October). During winter, hen harriers occur throughout the country, although in small numbers.

#### Temporal and spatial patterns of occurrence in the study area

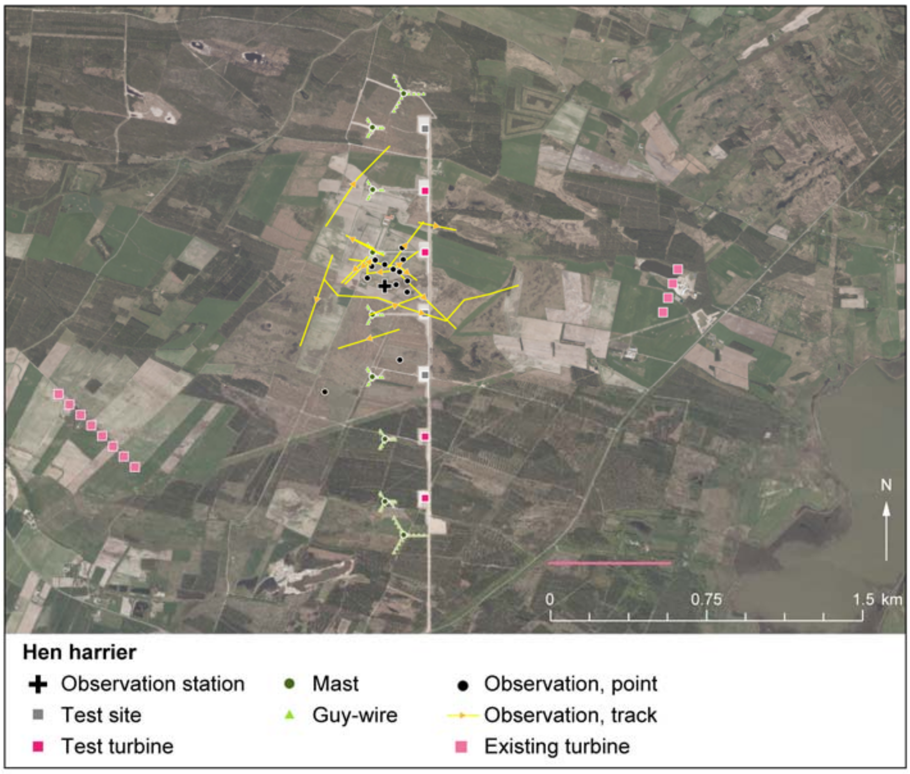
Small numbers of hen harriers were observed in September-December and in March near the observation station in the central part of the study area (Tab. 13, Fig. 35). To some extent this may reflect difficulties detecting low-flying individuals at longer distances. The hen harriers observed in the study area were probably autumn and spring staging individuals of unknown origin.

**Table 13.** Numbers of hen harriers passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 0/0 | 1/28 | 1/22 | 3/79 | 2/53 | 0/0 | 0/0 | 1/28 | 0/0 | 0/0 |
| South | 0/0 | 0/0 | 1/23 | 2/53 | 1/27 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |
| Total | 0/0 | 1/28 | 2/45 | 5/132 | 3/80 | 0/0 | 0/0 | 1/28 | 0/0 | 0/0 |

Altogether, 3.6% and 3.6% of the observed individuals and flocks, respectively, of hen harriers occurred at rotor height (min. 45 - max. 222 m), whereas 96.4% and 96.4% of individuals and flocks, respectively, were below rotor height (Fig. 36).

**Figure 35.** Overall flight patterns of hen harriers in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (885 m) from the observer within which 90% of the observation points were located.



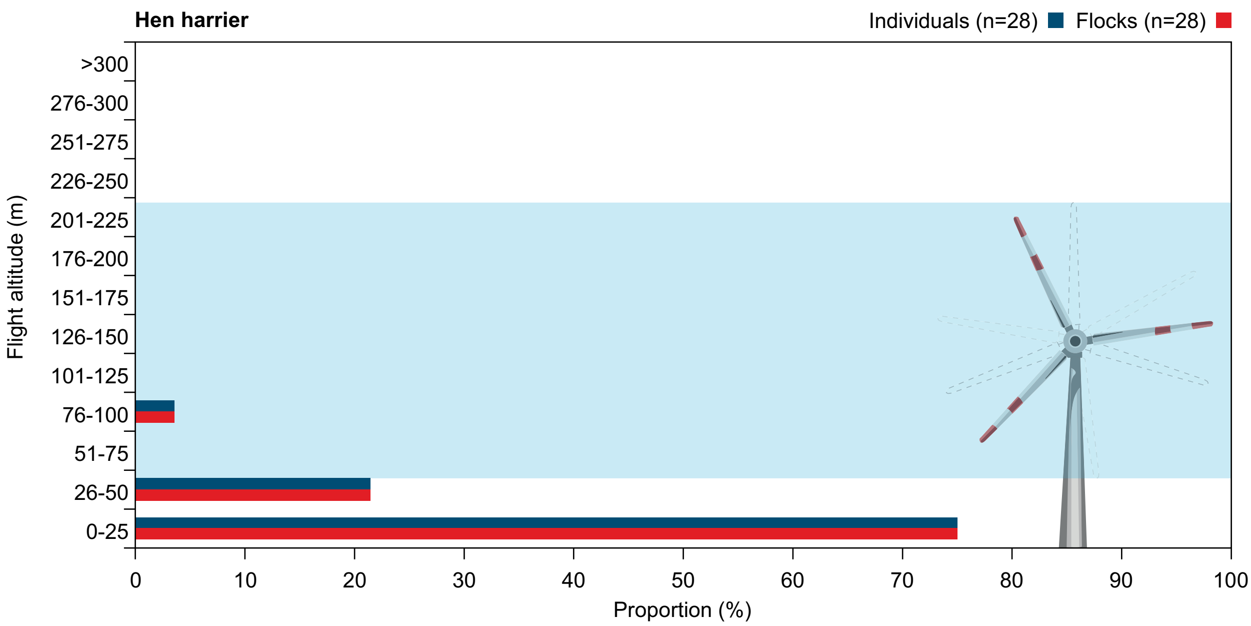




**Figure 36.** Flight altitudes of hen harriers expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

## Avoidance

The significant interaction effect between distance to the study area and the baseline versus post-construction indicates that hen harriers changed their flight altitude in relation to the wind turbines (Tab. B1). The two slope estimates between distance to turbines and altitude were positive for both baseline and post-construction studies (Tab. B2). Post-construction gave the largest positive slope, which may suggest that during the post-construction study hen harriers flew at lower altitude near the turbines or that the turbine area was used less for soaring during the post-construction study relative to the baseline study (Tab. B2).

### Estimate of collision risk at turbines and other structures

The estimated number of collisions between hen harriers and wind turbines is negligible (0.004-0.008). The estimate is similar to the result obtained during the baseline studies (0.005 collision per year), although this covered only part of the year. The post-construction study confirmed that the study area is only used occasionally by hen harriers and we therefore still expect the risk of collisions with turbines and other structures at the test centre to be of minor importance, although low visibility may increase the risk of collisions.

It should be noted that these results are supported by other studies, which typically have shown a strong propensity for hen harriers to fly at low elevations (Fig. 37). In general, it seems that hen harriers do not appear to be susceptible to colliding with turbine blades and that collision mortality should rarely be a serious concern (Whitfield & Madders 2005).

**Figure 37.** A male hen harrier foraging in the study area. © Jørgen Peter Kjeldsen.

### Intermediate assessment

Hen harrier is an extremely rare and irregular breeding bird in Denmark and therefore vulnerable to additional mortality. Therefore, in the case of a collision between a breeding bird and a turbine or other structures, a relatively large proportion of the Danish population would be affected. This also applies to the scarce regional population. However, considering that absence of breeding pairs in north Jutland and the relatively limited occurrence of staging or overwintering individuals in the study area, which probably originate from north Scandinavian breeding populations, we still consider the potential negative effects on this population to be negligible.

## Buzzard

### General occurrence

Buzzard is the most common breeding bird of prey in Denmark. In recent years, the population has increased to 6,000 pairs. During spring and autumn migration, buzzards from Norway, Sweden and Finland pass through Denmark. Many of the Scandinavian buzzards overwinter in Denmark.

### Temporal and spatial patterns of occurrence in the study area

Buzzards were observed throughout the study period. Peak numbers were observed in early autumn and late spring. In autumn, the peak coincided with the timing of the southward migration of Scandinavian buzzards, whereas the peak in spring was somewhat later than the time of the spring migration, which normally takes place from mid-March-April (Tab. 14).

**Table 14.** Numbers of buzzards passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 22/637 | 21/585 | 25/553 | 7/184 | 3/79 | 6/169 | 6/206 | 22/621 | 25/715 | 38/1112 |
| South | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 |
| Total | 22/637 | 21/585 | 25/553 | 7/184 | 3/79 | 6/169 | 6/206 | 22/621 | 25/715 | 38/1112 |

Buzzards were observed throughout the study area, although fewer observations were made in the southern parts (Fig. 38).This was also the case during the baseline studies and may reflect that low flying individuals and flocks may be difficult to see at greater distances. The overall flight pattern confirms the findings of the baseline studies that the majority of buzzards observed in the study area were local and staging individuals commuting between roosts and different feeding areas and not true migrants.

Altogether, 46.0% and 42.5% of the observed individuals and flocks, respectively, of buzzards occurred at rotor height (min. 45 - max. 222 m), whereas 54.0% and 57.5% of individuals and flocks, respectively, were outside rotor height (Fig. 39).

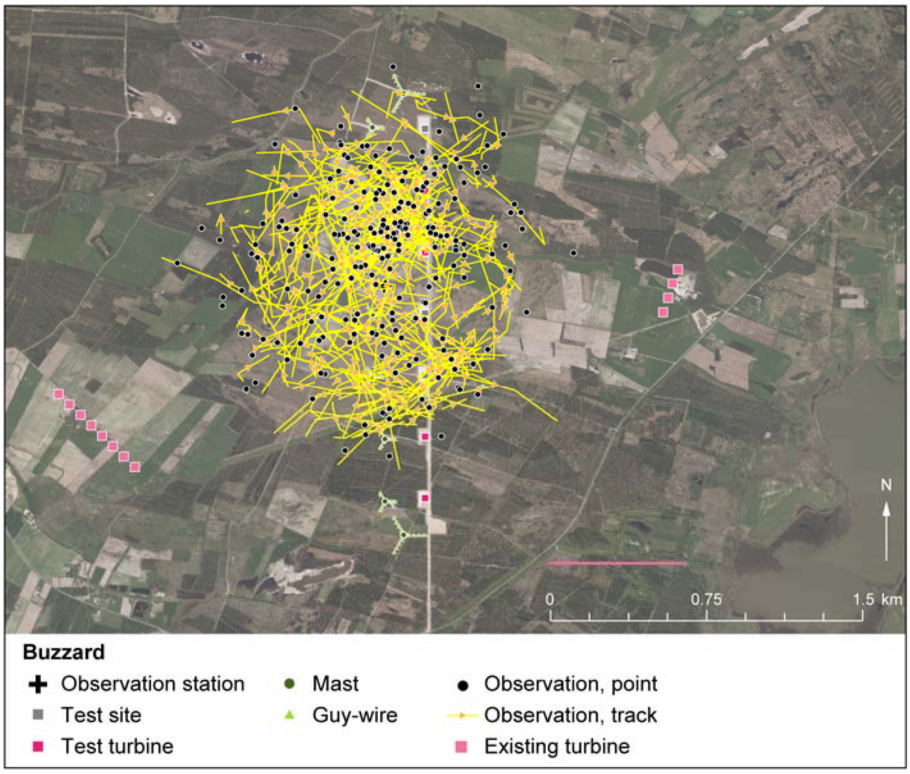
### Avoidance

When we compared flight patterns of buzzards obtained in the baseline and the post-construction studies, there was no significant effect of 1) the distance and 2) the interaction effect between distance and the two study years (Tab. B1). The non-significant interaction effect indicates that buzzards did not alter their flight altitude in relation to distance during the post-construction study compared to the baseline. The non-significant effects of distance suggest that buzzards did not alter their flight altitude in relation to the distance to the wind turbines and other structures in general.

### Estimate of collision risk at turbines and other structures

An estimated 0.8-1.7 collisions between buzzards and wind turbines are expected to take place each year. The estimate is similar to the result obtained during the baseline studies (0.71 collision per year), although the baseline study covered only part of the year.

**Figure 38.** Overall flight patterns of buzzards in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (1,276 m) from the observer within which 90% of the observation points were located.



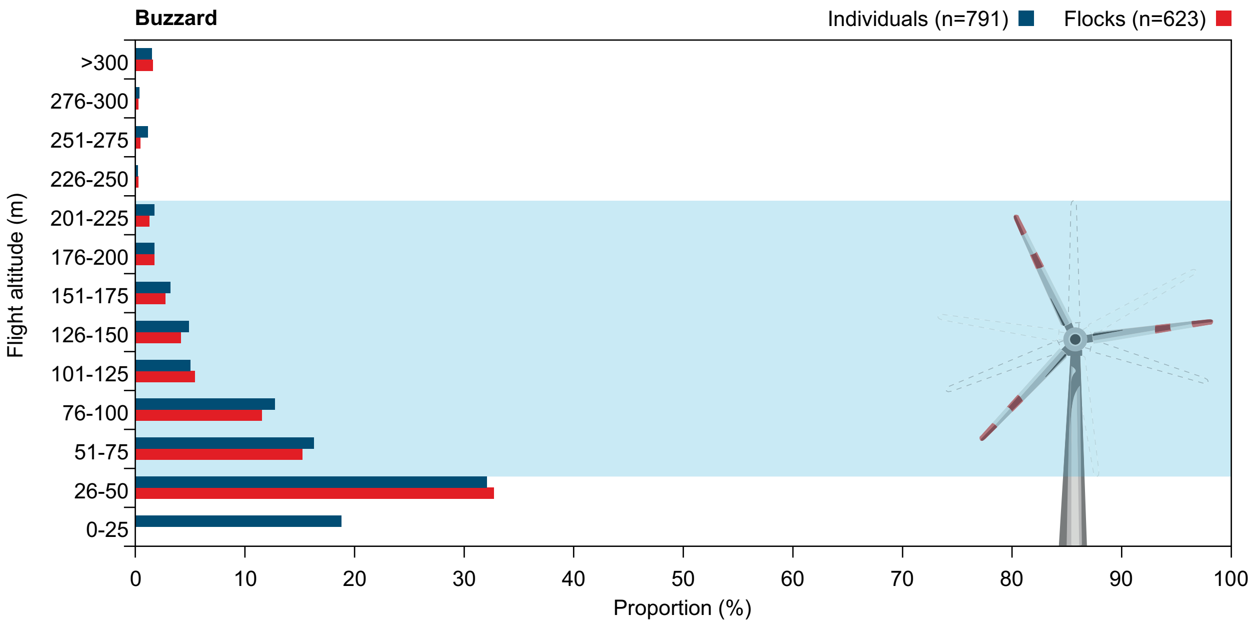




**Figure 39.** Flight altitudes of buzzards expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

Even though more buzzards were observed in the study area during the post-construction studies than during the baseline studies, only few collisions are expected. This is primarily a result of the low flight height of this species. We therefore expect the risk of collisions with turbines and other structures at the test centre to be of minor importance, although low visibility may increase the risk of collisions.

It should be noted that on some occasions buzzards were observed perching on guy wires, which may potentially increase the risk of collisions, particularly during periods with low visibility.

### Intermediate assessment

The estimated collision frequency corresponds to 0.02% of the size the Danish breeding population, which amounts to 6.000 pairs. Although the size of the regional population in northwest Jutland remains unknown and the calculated number of collisions must be regarded as a crude estimate, the potential impact of the combined structures at test centre on the national and regional populations of buzzards is still considered to be insignificant.

## Common crane

### General occurrence

Common crane is a scarce breeding bird in Denmark. In recent years, the population has increased to around 140-168 pairs the majority of which breeds in northwest Jutland (Nyegaard 2012). During spring and autumn migration, common cranes from Scandinavia pass through Denmark. In mild winters, some individuals may overwinter. In Denmark, the most important breeding sites, some of which have been designated SPAs for this species, are located in Thy, near the test centre. In recent years, nearby Vejlerne has become an important autumn staging site (September-November) for common crane with more than 200 individuals present. In recent years, common crane has become established as a breeding bird in the study area. In 2014, at least three territories were identified in the northern part of the study area.

### Temporal and spatial patterns of occurrence in the study area

Common cranes were observed in the study area in August-September and in February-May, No observations were made from October-January. Highest numbers were observed in late summer and early autumn, which probably is a result of the regional breeding population concentrating in nearby Vejlerne (Tab. 15). Many of the individuals observed in spring were probably local breeders and individuals that have not reached the age of maturity (4 years).

The temporal pattern is similar to what was observed during the baseline study, although no data were collected in early spring 2011.

**Table 15.** Numbers of common cranes passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 15/434 | 13/362 | 0/0 | 0/0 | 0/0 | 0/0 | 5/171 | 10/282 | 9/257 | 3/88 |
| South | 0/0 | 1/27 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 2/57 | 2/60 |
| Total | 15/434 | 14/389 | 0/0 | 0/0 | 0/0 | 0/0 | 5/171 | 10/282 | 11/314 | 5/148 |

Most of the common cranes were tracked near the observation station in the central part of the study area. In contrast to the baseline studies, where the majority of flocks moved in an eastwesterly direction, there was no clear pattern in the movements observed during the post-construction studies (Fig. 40). However, the pattern obtained during the post-construction studies support the initial assumption that the common cranes observed in the study area are not migrants but mainly commute between feeding areas and nocturnal roosts or breeding sites.

Altogether, 35.8% and 17.9% of the observed individuals and flocks, respectively, of common cranes occurred at rotor height (min. 45 - max. 222 m), whereas 64.2% and 82.1% of individuals and flocks, respectively, were outside rotor height (Fig. 41).

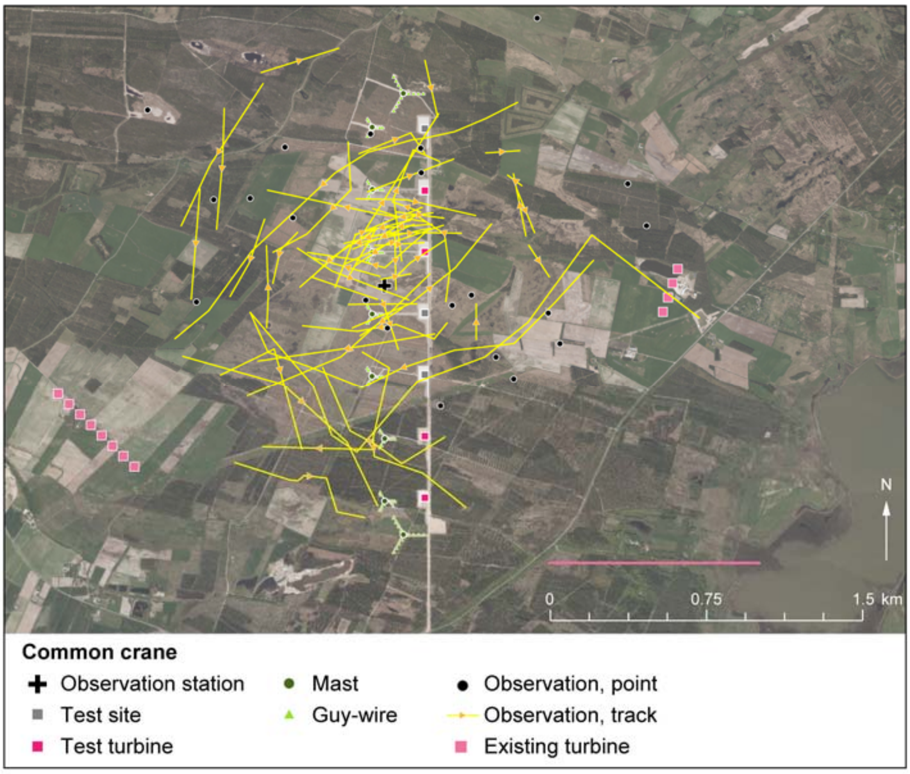



**Figure 40.** Overall flight patterns of common cranes in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (2,025 m) from the observer within which 90% of the observation points were located.

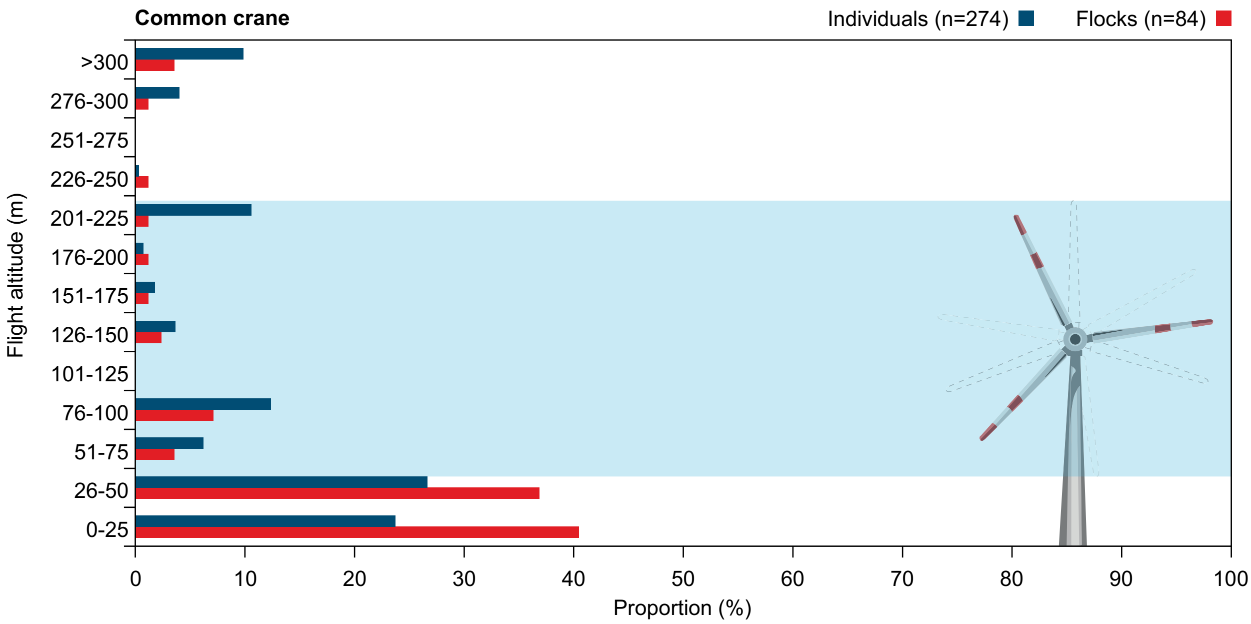



**Figure 41.** Flight altitudes of common cranes expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

### Avoidance

When we compared flight patterns of cranes obtained in the baseline and the post-construction studies, there was no significant effect of the interaction effect between distance and the two study years (Tab. B1). The non-significant interaction effect indicates that cranes did not alter their flight altitude in relation to distance during the post-construction study compared to the baseline.

The overall significant effects of distance suggest that cranes altered their flight altitude in relation to the distance to the study area. The positive parameter estimate for distance suggests that cranes were observed to fly at higher altitudes with increasing distance to the study area (Tab. B4).

### Estimate of collision risk at turbines and other structures

An estimated 0.01-0.03 collisions between common cranes and wind turbines are expected to take place each year. This estimate is somewhat lower than the result obtained during the baseline studies (0.37 collision per year), although this covered only part of the year.

Since no data have been collected during summer it still remains unknown whether non-breeding individuals may use the study area during this period. With regard to local breeders, we assume that flight activity is limited at this time of the year since adults are expected to be guarding nests and young.

The tendency for common cranes to be more active around and before dawn and the fact that that cranes are characterized by high wing loading and a low aspect ratio, resulting in rapid flight and low manoeuvrability (Bevanger 1998), means that there may also be an additional risk of collisions between this species and other structures at the test centre, e.g. guy wires and masts. This is particularly the case in situations where visibility is reduced due to adverse weather conditions.

### Intermediate assessment

Common crane is a scarce breeding bird in Denmark, although the population has increased in recent years. The relatively small size of the population means that in the case of a collision between a breeding bird and a turbine or mast, a relatively large proportion of the Danish and the regional population would be affected. Although, the post-construction study confirmed our preliminary results that only a small number of collisions are expected, the establishment of common crane as a breeding bird within the study area may potentially increase the risk of collisions with turbines and masts.

On this basis, common crane will continue to be included in the post-construction programme as a focal species to obtain more data to support the final assessment of the potential impact of the test centre on this species.

## Golden plover

### General occurrence

Golden plover is an extremely rare breeding bird in Denmark. The Danish breeding birds belong to the southern form *Pluvialis a. apricaria* that, similarly to the northern golden plovers *Pluvialis a. altifrons*, winter in Western Europe. From March to May, 70,000-100,000 northern golden plovers stage in Denmark, particularly in the Wadden Sea, west and north Jutland. From July to November, when numbers peak, the birds are dispersed throughout the country.

### Temporal and spatial patterns of occurrence in the study area

Golden plovers occurred in the study area from September-November and from March-May.

In autumn, highest numbers of golden plovers were registered in November, whereas in spring highest numbers occurred in April (Tab. 16). It is difficult to compare this pattern to the observations made during the baseline studies, since one single observation at this time accounted for 96% of the total number of individuals registered on visual transects during the study period. It should also be noticed that during the baseline no data were collected during early spring.

**Table 16.** Numbers of golden plovers passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 9/260 | 90/2508 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 35/988 | 0/0 | 0/0 |
| South | 10/285 | 31/834 | 800/18321 | 790/20761 | 0/0 | 0/0 | 0/0 | 0/0 | 1200/34311 | 90/2711 |
| Total | 19/545 | 121/3342 | 800/18321 | 790/20761 | 0/0 | 0/0 | 0/0 | 35/988 | 1200/34311 | 90/2711 |

Golden plovers were mainly observed near the central observation station (Fig. 42). This was also the case during the baseline studies.


**Figure 42.** Overall flight patterns of golden plovers in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (1,118 m) from the observer within which 90% of the observation points were located.

Altogether, 87.4% and 56.3% of the observed individuals and flocks, respectively, of golden plovers occurred at rotor height (min. 45 - max. 222 m), whereas 12.6% and 43.8% of individuals and flocks, respectively, were below rotor height (Fig. 43).

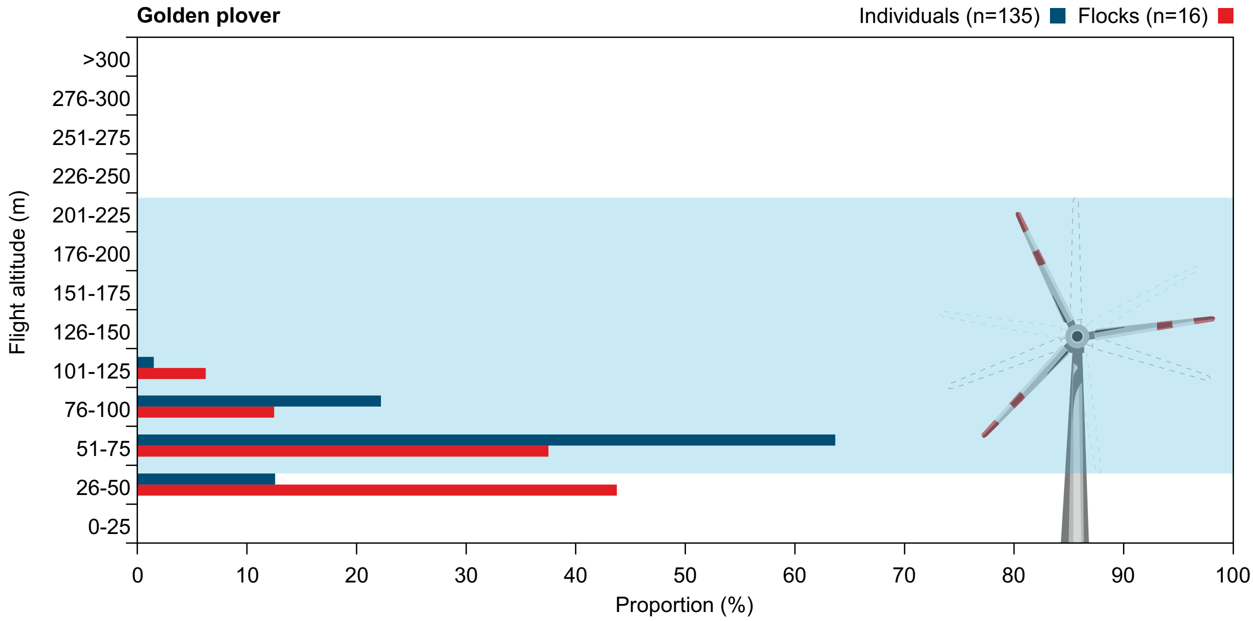



**Figure 43.** Flight altitudes of golden plovers expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

### Avoidance

When we compared flight patterns of golden plover obtained in the baseline and the post-construction studies, there was no significant effect of 1) the distance and 2) the interaction effect between distance and the two study years (Tab. B1). The non-significant interaction effect indicates that golden plovers did not alter their flight altitude in relation to distance during the post-construction study compared to the baseline. The non-significant effects of distance suggest that golden plovers did not alter their flight altitude in relation to the distance to the wind turbines and other structures in general.

### Estimate of collision risk at turbines and other structures

An estimated 3-7 collisions between golden plovers and wind turbines are expected to take place each year. This is somewhat lower than the estimate obtained from the baseline studies (65), although the baseline study covered only some of the time during which golden plovers are present in northwest Jutland. The post-construction study therefore confirmed the result of the baseline study that only a few collisions between golden plovers and wind turbines are expected to occur each year. It should be noticed that during the baseline study one single observation of golden plovers accounted for 96% of the total number of individuals registered on visual transects.

We assume that the majority of golden plovers registered in the study area were spring and autumn staging individuals moving between feeding areas. This is supported by the relatively low flight altitude registered for golden plovers. We consider it to be highly unlikely that individuals from the Danish breeding population were among the golden plovers registered in the study area.

Since golden plovers feed during both day and night there may be an additional risk of collisions between this species and other structures at the test centre, e.g. guy wires and masts. During the day, this may also be the case in situations where visibility is reduced due to adverse weather conditions.

#### Intermediate assessment

The results from the post-construction study support our preliminary assessment that the potential impact of the structures at the test centre on the population of golden plovers is considered to be insignificant. Although the calculated number of collisions must be regarded as a crude estimate, the potential impact of the combined structures at the test centre on golden plovers is still considered to be insignificant.

### Wood pigeon

#### General occurrence

The Danish population of wood pigeons has increased in recent years and more than 250,000 pairs breed throughout the country. During migration in autumn and spring wood pigeons originating from breeding areas in Scandinavia pass through the country. Some of these stay to overwinter.

#### Temporal and spatial patterns of occurrence in the study area

Wood pigeons were registered in the study area throughout the study period. Most birds occurred in the study area in October, which coincided with the peak migration period of this species (Tab. 17). This was also the case during the baseline studies, although numbers were somewhat higher during the post-construction period. Outside the migration periods the birds observed in the study area were probably a mixture of local and staging individuals commuting between roosts and different feeding areas.

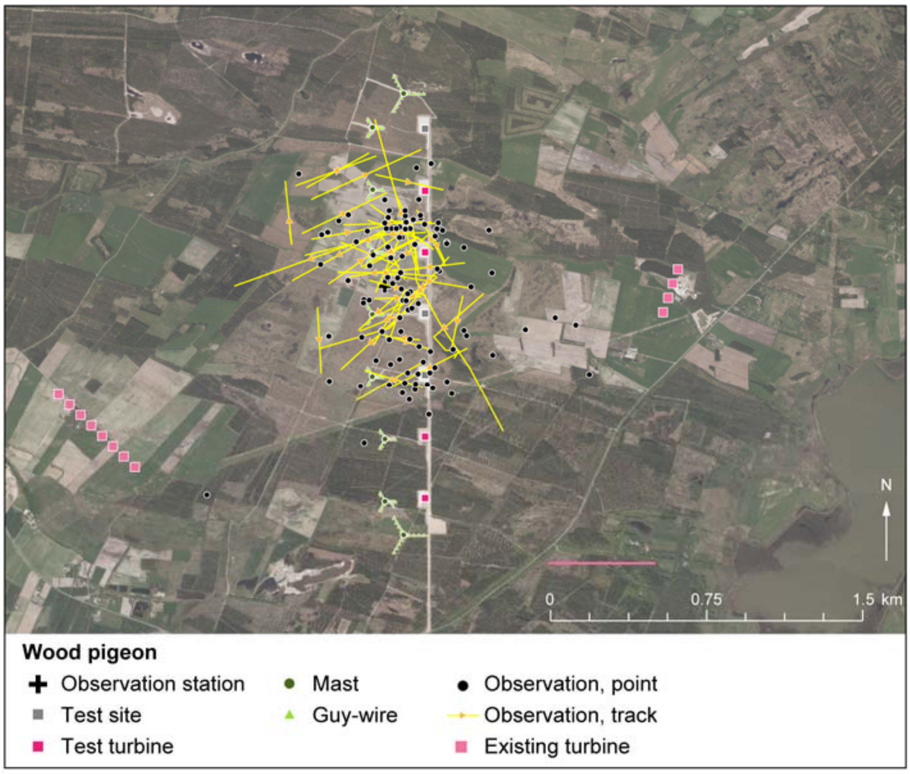
**Table 17.** Numbers of wood pigeons passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 61/1765 | 81/2257 | 34/752 | 3/79 | 1/26 | 0/0 | 3/103 | 21/593 | 20/572 | 46/1346 |
| South | 37/1054 | 65/1748 | 262/6000 | 88/2313 | 2/55 | 6/169 | 88/3116 | 41/1204 | 21/600 | 31/934 |
| Total | 98/2819 | 146/4005 | 296/6752 | 91/2392 | 3/81 | 6/169 | 91/3219 | 62/1797 | 41/1172 | 77/2280 |

Most wood pigeons were observed close to the observation station. A higher number of tracks was obtained during the post-construction studies, which may reflect the removal of trees, which otherwise obscured the view during the baseline studies. However, the low flight altitude of wood pigeons may hinder the detection of individuals and flocks at larger distances. Therefore more individuals may have occurred in other parts of the study area (Fig. 44).

Altogether, 32.3% and 16.2% of the observed individuals and flocks, respectively, of wood pigeons occurred at rotor height (min. 45 - max. 222 m), whereas 67.7% and 83.8% of individuals and flocks, respectively, were below rotor height (Fig. 45).

Figure 44. Overall flight patterns of wood pigeons in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (1,005 m) from the observer within which 90% of the observation points were located.



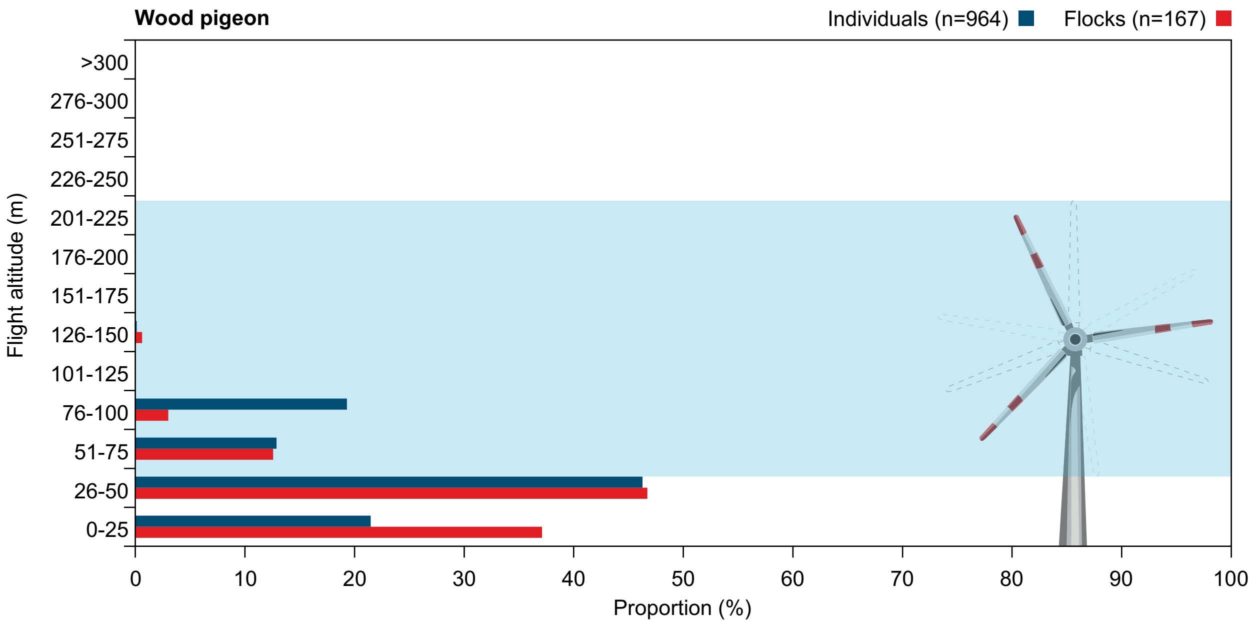




**Figure 45.** Flight altitudes of wood pigeons expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

### Avoidance

When we compared flight patterns of wood pigeons obtained in the baseline and the post-construction studies, there was no significant effect of 1) the distance and 2) the interaction effect between distance and the two study years (Tab. B1). The non-significant interaction effect indicates that wood pigeons did not alter their flight altitude in relation to distance during the post-construction study compared to the baseline. The non-significant effects of distance suggest that wood pigeons did not alter their flight altitude in relation to the distance to the wind turbines and other structures in general.

### Estimate of collision risk at turbines and other structures

An estimated 0.5-1.2 collisions between wood pigeons and wind turbines are expected to take place each year. This is somewhat lower than the estimate obtained from the baseline studies (0.91), although the baseline study covered only part of the year. The post-construction study therefore confirmed the result of the baseline study that only a few collisions between wood pigeons and wind turbines are expected to occur each year.

There were no indications of extensive seasonal migration taking place during the migration periods and we therefore assume that the majority of wood pigeons registered in the study area were either local or staging birds. This is supported by the relatively low flight altitude observed among wood pigeons.

There may be an additional risk of collisions between wood pigeons and other structures at the test centre, e.g. guy wires and masts. This is particularly the case in situations where visibility is reduced due to adverse weather conditions, or around dusk.

### Intermediate assessment

The results from the post-construction study support our preliminary assessment that the potential impact of the structures at the test centre on the population of wood pigeons is considered to be insignificant. Although the calculated number of collisions must be regarded as a crude estimate, the potential impact of the combined structures at the test centre on wood pigeons is still considered to be insignificant.

## Common raven

### General occurrence

In recent decades, the Danish population of common raven has increased dramatically and today more than 500 breeding pairs are scattered throughout the country. However, relatively few pairs are found in northwest Jutland.

### Temporal and spatial patterns of occurrence in the study area

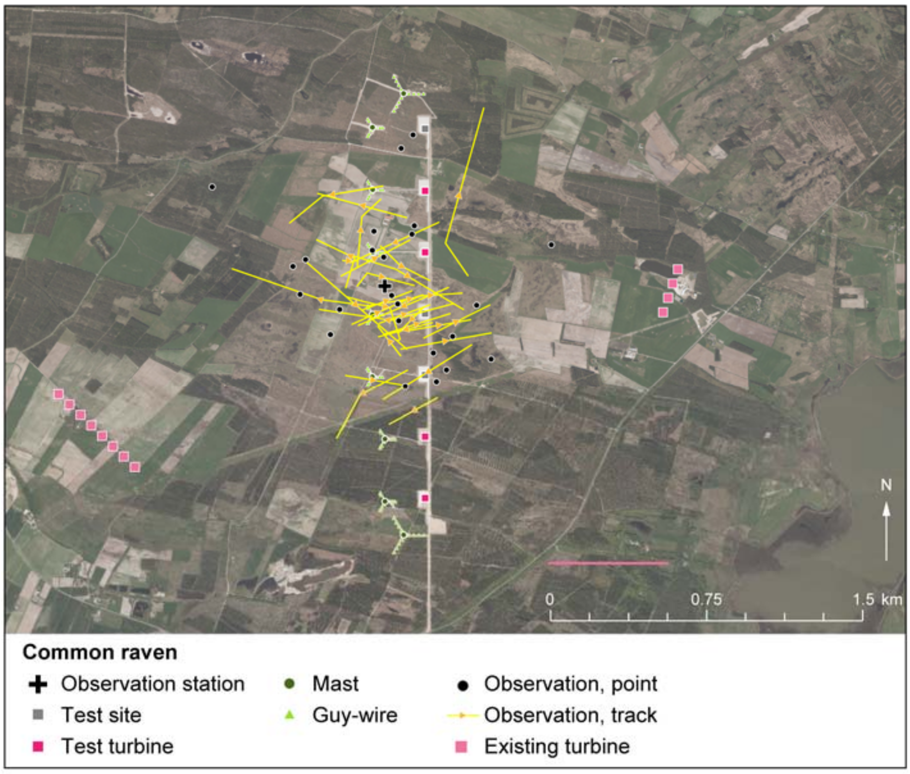
Common raven occurred in small numbers from August-April. Most birds were observed in August and November (Tab. 18).

**Table 18.** Numbers of common ravens passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 0/0 | 1/28 | 0/0 | 4/105 | 1/26 | 1/28 | 0/0 | 1/28 | 3/86 | 0/0 |
| South | 8/228 | 0/0 | 1/23 | 5/131 | 1/27 | 2/56 | 4/142 | 3/88 | 3/86 | 0/0 |
| Total | 8/228 | 1/28 | 1/23 | 9/236 | 2/53 | 3/84 | 4/142 | 4/116 | 6/172 | 0/0 |

Most common ravens were observed close to the central observation station. This was also the case during the baseline studies and this pattern probably reflects that in most cases flight altitude of common ravens was low making it difficult to detect individuals at larger distances. Therefore more individuals may have occurred in other parts of the study area (Fig. 46).

**Figure 46.** Overall flight patterns of common ravens in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (1,145 m) from the observer within which 90% of the observation points were located.



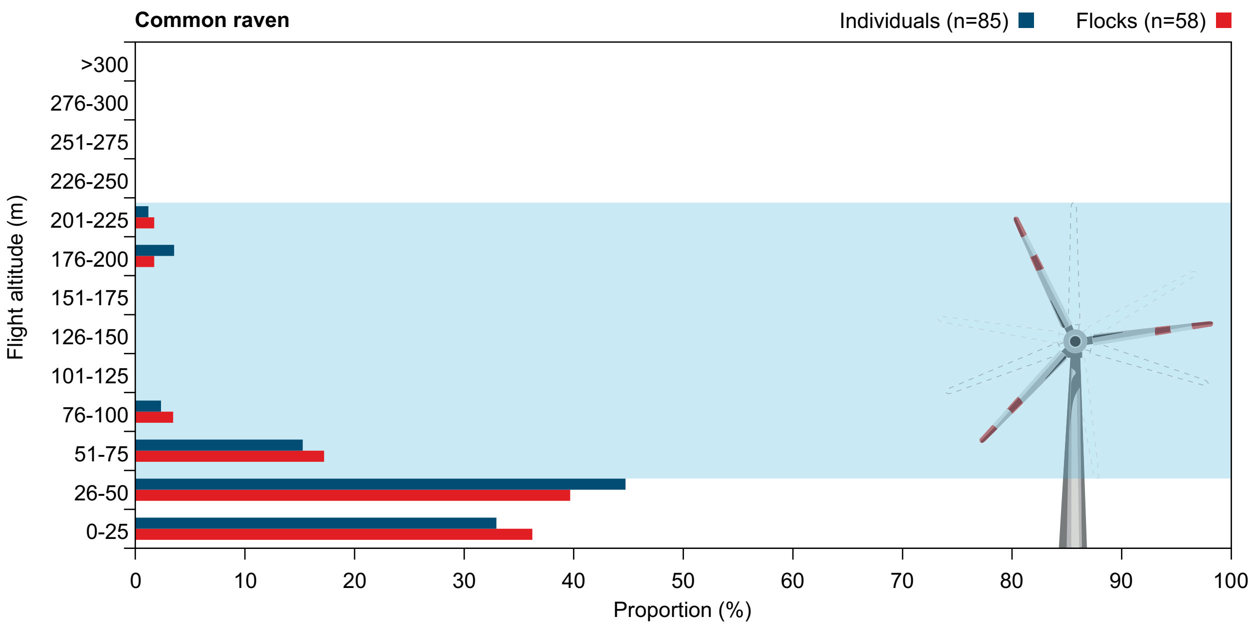




**Figure 47.** Flight altitudes of common ravens expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

Altogether, 22.4% and 24.1% of the observed individuals and flocks, respectively, of common ravens occurred at rotor height (min. 45 - max. 222 m), whereas 77.6% and 75.9% of the remainder of individuals and flocks, respectively, were below rotor height (Fig. 47).

### Avoidance

When we compared flight patterns of ravens obtained in the baseline and the post-construction studies, there was no significant effect of 1) the distance and 2) the interaction effect between distance and the two study years (Tab. B1). The non-significant interaction effect indicates that common ravens did not alter their flight altitude in relation to distance during the post-construction study compared to the baseline. The non-significant effects of distance suggest that common ravens did not alter their flight altitude in relation to the distance to the wind turbines and other structures in general.

### Estimate of collision risk at turbines and other structures

Less than one (0.03-0.05) collision between common raven and wind turbines is expected to take place each year. This estimate is similar to the result obtained during the baseline studies (0.08 collision per year), although this covered only part of the year.

The post-construction study therefore confirmed the result of the baseline study that only a few collisions between common ravens and wind turbines are expected to occur each year.

There were no indications of extensive seasonal migration taking place during the migration periods and we therefore assume that the majority of common ravens registered in the study were local birds. This was also the case during the baseline study.

There may be an associated risk of collisions between common ravens and other structures at the test centre, e.g. guy wires and masts. This is particularly the case in situations where visibility is reduced due to adverse weather conditions and around dusk. However, common raven is not active during night, when risk of collision is highest.

### Intermediate assessment

Since common raven is a scarce breeding species in northwest Jutland, a collision between a breeding bird and a turbine or other structures will affect a relatively large proportion of the local population. On the other hand, ravens typically have large non-breeding elements to their population, so the removal of breeders will potentially enable recruitment from these birds. Altogether, in the light of the low risk of collision between common ravens and the combined structures at the test centre and the dramatic increase in the population during the last decades, we still consider the potential negative effect on common raven to be negligible.

## Passerines

### General occurrence

Passerines (Order: Passeriformes) comprise a diverse group of species ranging from the very small goldcrests (9 cm body length) to the larger ravens (65 cm body length). Passerines occur in Denmark throughout the year both as breeding birds and as migrants, mainly from Northern Scandinavia, which stage or overwinter for shorter or longer periods. With the onset of cold weather and snow, many passerines migrate further south. Passerine migrants are usually divided into diurnal (e.g. swallows, larks (Fig. 48), wagtails and pipits) and nocturnal migrants (e.g. thrushes, warblers and flycatchers). However, this strict separation is weakened amongst some species, which may prolong their migration into day or night when crossing ecological barriers, such as oceans. Here we focus on passerines observed during daytime, whereas the nocturnal migration is addressed below. Corvids (e.g.hooded crow, jackdaw) have been excluded from this part of the analysis and instead common raven is included as a representative of this group.

**Figure 48.** A male skylark advertises its territory in the study area. © Jørgen Peter Kjeldsen.

### Temporal and spatial patterns of occurrence in the study area

Passerines occurred in the study area throughout the study period (Tab. 19). Numbers peaked from August-November, which probably reflects an influx of northern Scandinavian birds at this time. Even though the calculated numbers may seem high, it is important to keep in mind that these include a range of species (Appendix B1).

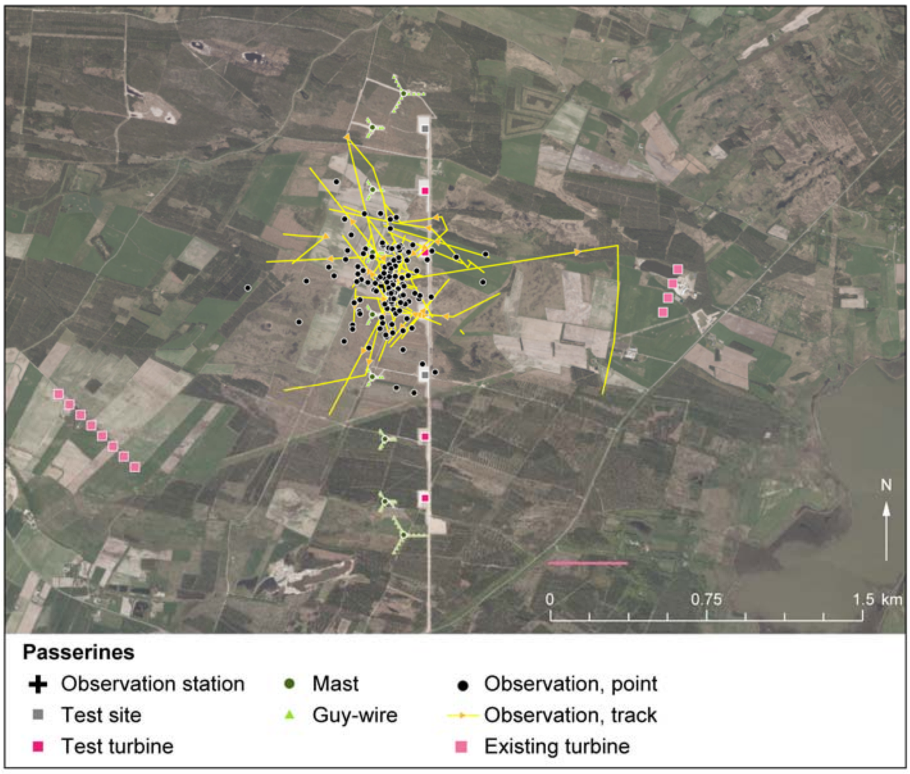
**Table 19.** Numbers of passerines passing the study area on visual transects during the post-construction study period expressed as observed/calculated number of individuals.

| | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|
| North | 462/13367 | 323/9001 | 363/8026 | 928/24387 | 300/7946 | 466/13148 | 31/1062 | 586/16545 | 74/2116 | 32/936 |
| South | 478/13621 | 1545/41542 | 578/13237 | 585/15373 | 99/2707 | 74/2088 | 58/2054 | 248/7282 | 124/3545 | 25/753 |
| Total | 940/26988 | 1868/50543 | 941/21263 | 1513/39760 | 399/10653 | 540/15236 | 89/3116 | 834/23827 | 198/5661 | 57/1689 |

For the smaller species such as swallows, wagtails, finches and thrushes, detection is difficult at distances beyond 5-600 m, unless birds occur in dense flocks. Therefore passerines were mainly observed near the observation stations and only few flight tracks were obtained (Fig. 49). This was also the case during the baseline studies.

Altogether, 12.6% and 43.8% of the observed individuals and flocks, respectively, of passerines occurred at rotor height (min. 45 - max. 222 m), whereas 87.4% and 56.3% of the remainder of individuals and flocks, respectively, were outside rotor height (Fig. 50).

**Figure 49.** Overall flight patterns of passerines in the study area, August 2013 – May 2014. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Black arrows indicate the flight direction, and the red bar indicates the distance (745 m) from the observer within which 90% of the observation points were located.



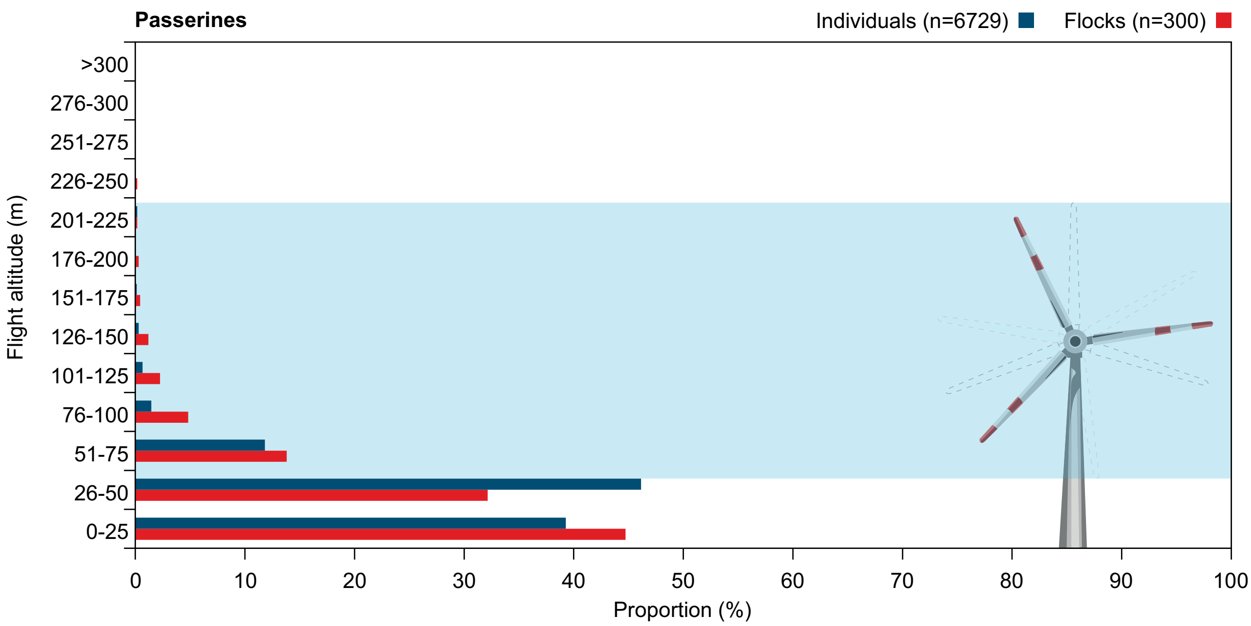




**Figure 50.** Flight altitudes of passerines expressed as the proportion of individuals (blue) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude covered by the total sweep area of the wind turbines (min. 45 – max. 222 m).

### Avoidance

When we compared flight patterns of passerines obtained in the baseline and the post-construction studies, there was no significant effect of 1) the distance and 2) the interaction effect between distance and the two study years (Tab. B1). The non-significant interaction effect indicates that passerines did not alter their flight altitude in relation to distance during the post-construction study compared to the baseline. The non-significant effects of distance suggest that passerines did not alter their flight altitude in relation to the distance to the wind turbines and other structures in general.

#### Estimate of collision risk at turbines and other structures

An estimated 3-5 collisions between passerines and wind turbines are expected to take place each year.

The post-construction study confirmed the pattern from the baseline that a relatively small proportion of the passerines occurred at rotor height. Therefore the expected number of collisions between wind turbines and passerines during daytime is low.

No attempt was made to calculate collision estimates on the basis of the rather limited data, which was available from the baseline study. This was partly due to the fact that most passerines were observed close to the observation station and therefore not representative for the study area as a whole. This was also the case during the post-construction study, although this covered most of the year. Therefore the expected number of collisions, which is based on a relatively limited amount of data, should be interpreted with some caution.

It is important to notice that the difficulties detecting smaller passerines at distances beyond 5-600 m also applies to birds passing the test area at high altitudes. However, the relatively few observations of passerines at altitudes between 50-100 m indicate that this was not a case of birds being overlooked. On the basis of the relatively low flight altitude of passerines registered in the study area, we consider the majority of daytime passerines to be local birds moving between feeding areas. This was also the case during the baseline study.

The post-construction study confirmed the conclusion of the baseline study that migrating passerines are not concentrated in the study area.

The relatively low wing loading and high manoeuvrability of most passerines may contribute to reduce risk of collisions between passerines and the structures at the test centre. However, this may not be the case in situations, where visibility is reduced due to adverse weather conditions.

#### Intermediate assessment

In general, passerines are suggested to be among the bird species least susceptible to additional mortality from wind turbines and other structures. In addition, Erickson et al. (2005) point to the fact that even for nocturnal migrants global collision estimates clearly indicate that the numbers of casualties at wind farms are at least three orders of magnitudes lower than the numbers killed by collisions with buildings, power lines and air fields. Therefore, although the expected number of collisions for this group of species should be regarded as a crude estimate, we still consider the potential impact of the combined structures at the test centre on passerines active at daytime to be insignificant.

## Nightjar

### General occurrence

In Denmark, the breeding population of nightjars is concentrated in western and northern Jutland, with smaller numbers breeding in northern Zealand. In winter, the population leaves the country. In recent years, 5-6 breeding pairs have been registered in the vicinity of the study area (Niels Odder, pers. comm.).

### Temporal and spatial patterns of occurrence in the study area

The transect counts showed that nightjars were present in the study area during the breeding season. From July 7-20, we identified five territories on the basis of the presence of advertising males. Three of the territories were situated in the northern part of the study area, one was close to turbine test site 5 and one was situated east of turbine test sites 5-6 (Fig. 51). No nightjars were observed foraging around turbines.


**Figure 51.** The map shows where advertising males of nightjars were registered from July 7-20 2014.

The maximum flight height of territorial nightjars was measured to 14 m using laser range finder. The remainder of the individuals was all active below the treetops.

### Preliminary assessment

Little is known about the behaviour of nightjars in relation to land based wind turbines and the associated mortality risks. It has been suggested that foraging nightjars may be attracted to insects resting on turbine towers, which may increase the risk of fatalities.

It is important to notice that most of the nightjars registered in the study area probably were advertising males and not foraging individuals, which may exhibit a different behaviour and exploit the area differently.

The fact that no nightjars were found during the carcass searches in July-August 2014 indicates that the collision risk is low. However, at this stage we are unable to estimate the collision risk between turbines and nightjars and therefore the assessment of potential negative impacts at the local breeding population awaits further studies. This issue will therefore be addressed in the second post-construction study year, where we will focus on obtaining data on the behaviour and occurrence of nightjars, which may potentially be foraging in close proximity to the turbines.

## Nocturnal migrants

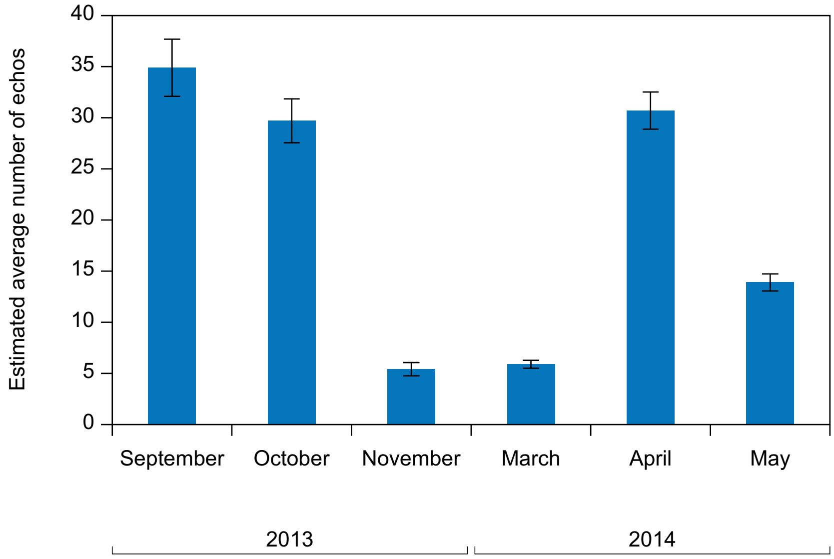
### General occurrence

Patterns of nocturnal migration at the species level are difficult to obtain under most circumstances, because of the difficulties of identifying radar echoes to species under cover of darkness. However, the speed of the flock, shape and size of radar echoes may give an indication of the type of migrants involved. On this basis of the baseline studies, we considered most of the nocturnal migrants at the test centre to be smaller passerines (i.e. warblers, thrushes), although there were indications that to some extent larger birds such as geese, ducks and swans, were also active during the night.

### Temporal patterns of occurrence in the study area

In autumn, migration intensity was highest in September and October, when a major influx of northern Scandinavian passerines, e.g. thrushes, warblers, is normally known to take place. In spring, migration intensity was highest in April, whereas in March and May the intensity was lower. This peak also coincided with the known northward migration of northern Scandinavian passerines (Fig. 52).

**Figure 52.** Migration intensity expressed as the number of echoes/screen shot/$km^3$ in autumn 2013 and spring 2014. Data were obtained using vertical radar.




The altitudinal distribution derived from radar studies showed that in spring more birds occurred at higher flight altitudes than during autumn (Fig. 53). This was most likely a result of genuine migrants dominating the sample in spring, whereas in autumn, local birds making shorter, local movements at lower altitudes dominate the sample throughout the night (shown for September 2013 in Fig. 54).

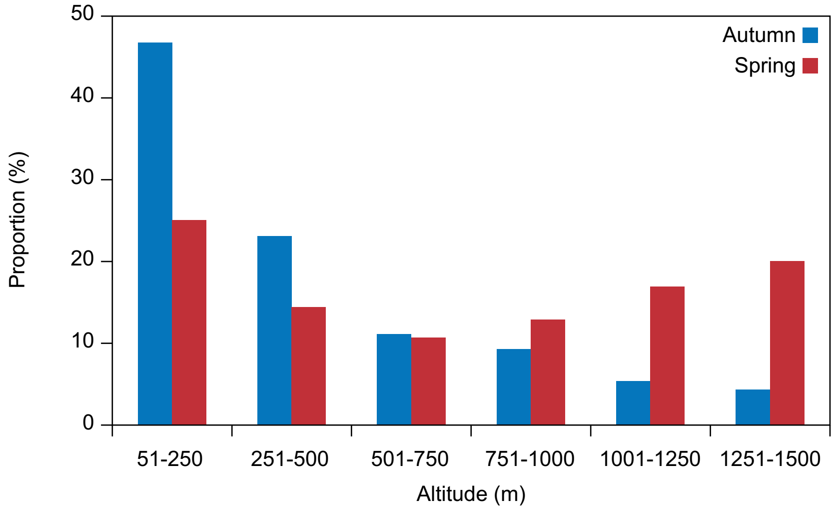



**Figure 53.** The altitudinal distribution of nocturnal migrants in autumn 2013 and spring 2014. Data were obtained using vertical radar.

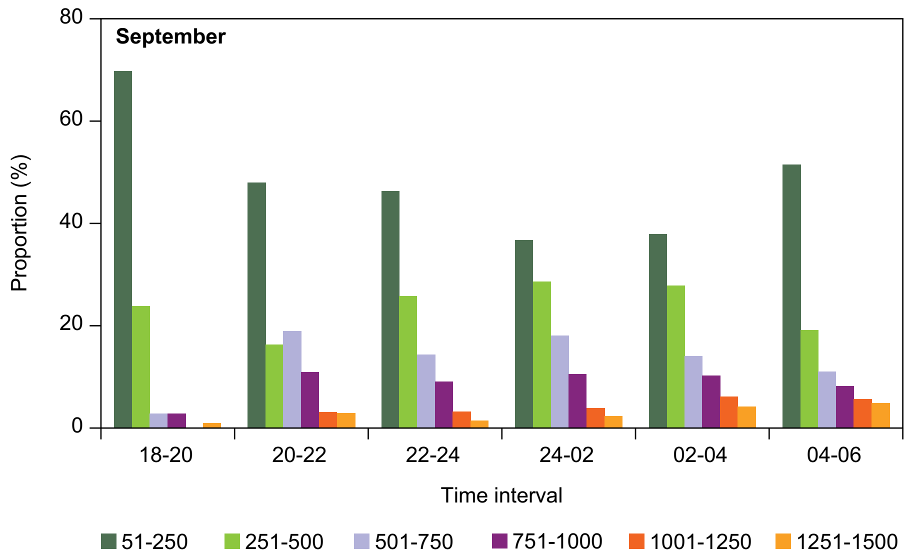
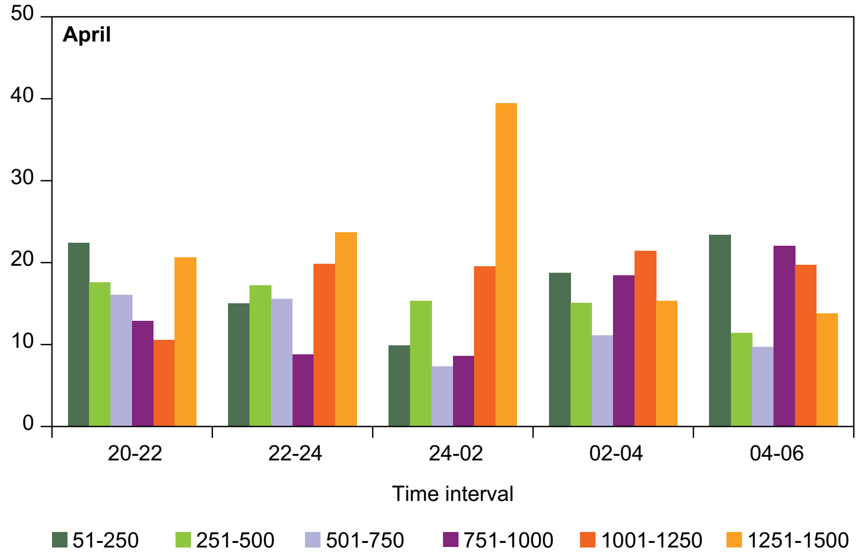



**Figure 54.** The relationship between flight altitude categories of nocturnal migrants and the time of the night, September 2013.

In spring 2013, the average flight altitude was highest during the middle of the night, which is a typical pattern of nocturnal migration. This was most likely a result of genuine migrants initiating and finishing their migration at dusk and dawn, respectively, and reaching their maximum migration height during the middle of the night. In addition, local breeding birds making relatively short movements between feeding areas and night roosts at lower altitudes may constitute a larger part of the individuals around dusk (as shown for April in Fig. 55).

Figure 55. The relationship between flight altitude categories of nocturnal migrants and the time of the night, April 2013.




During the peak migration in autumn 2013, migration intensity was highest in the middle of the night (shown for September in Fig. 56). In spring 2014, a similar pattern was observed (shown for April in Fig. 58). Outside the peak migration periods in both autumn 2013 (shown for November in Fig. 57) and spring 2014 (shown for March in Fig. 59), migration intensity was more evenly distributed throughout the night.

**Figure 56.** The relationship between migration intensity and the time of the night, September 2013.

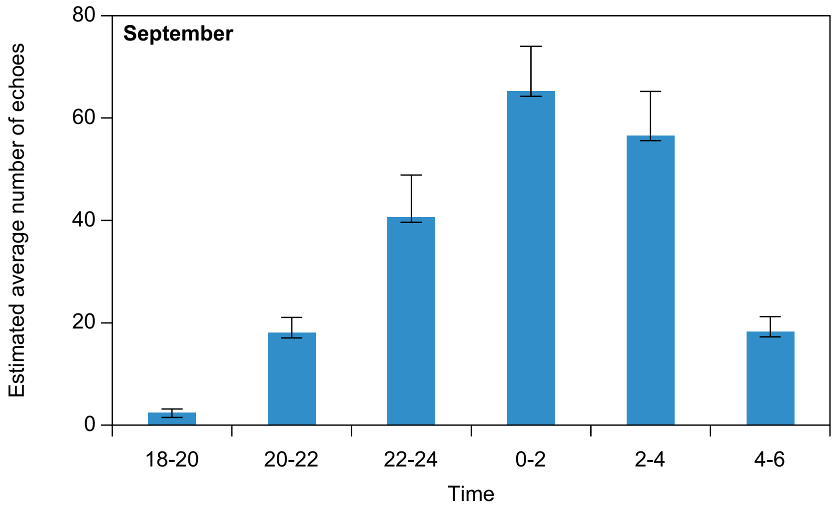


**Figure 57.** The relationship between migration intensity and the time of the night, November 2013.

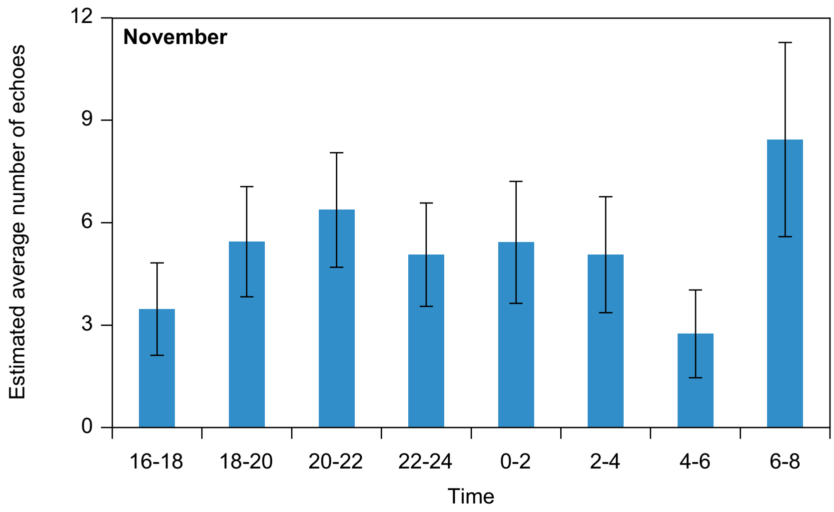



**Figure 58.** The relationship between migration intensity and the time of the night, March 2014.

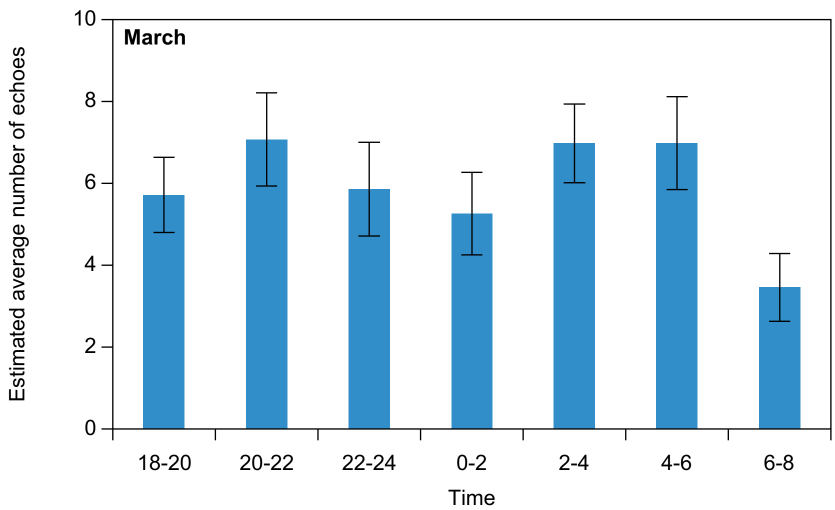
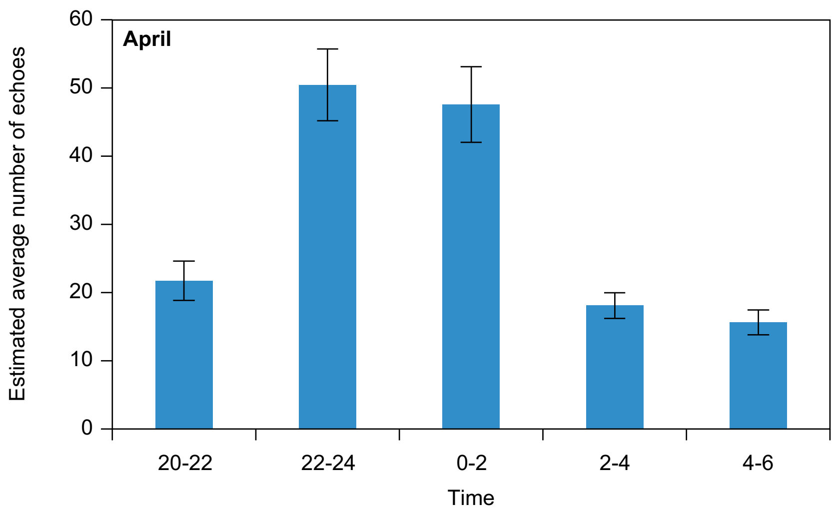



**Figure 59.** The relationship between migration intensity and the time of the night, April 2014.



### Intermediate assessment

The radar studies confirmed the results of the baseline studies that genuine nocturnal migration occurred in the study area. In contrast to the baseline studies where the pattern of nocturnal migration merely suggested a broad-fronted movement of passerines, which was outnumbered by the activity of local birds around dusk, the migration pattern observed during the post-construction study indicated that real migrants outnumbered the movements of local birds moving at lower altitudes. This was particularly the case in spring, when real migration took place to a larger extent in both study years.

In general, broad-fronted nocturnally migrating passerines are suggested to have a low risk of collision (Desholm 2006) and we assume that this is also the case in the Østerild area, which has no topographic characteristics that funnel migration into the test centre area. However, in contrast to the baseline study the pattern of nocturnal migration observed during the post-construction study merely resembled what we would expect if true migrants, i.e. birds performing seasonal movements over larger distances, typically at higher altitudes, dominated the sample.

In the current study year there was some suggestion that there were greater movements in the middle of the night (and less during the early and late hours of darkness) than during the baseline. This may be an artifact or suggest a change in the apparent dominance of true migrants (over local birds moving in the vicinity) during peak migration periods, which differed from the baseline study. Whether this is a result of different weather conditions leading to more migrants passing the study area, or to potential attraction to the lights at the aviation masts at the test centre is not clear. However, based on our measurements and modelling of daytime movements, we expected little or no differences in the numbers of collisions, a fact confirmed by the carcass searches which failed to find any corpses in the study year. On this basis, we conclude that despite these changes, the construction of the turbines has not resulted in any detectable collisions of nocturnally migrating passerines with the turbines and masts.

As mentioned above, several factors are likely to affect the variation in the number of collisions at wind turbines and other structures at the test centre. In addition, the reduced visibility at night in combination with the presence of structures in the strata preferred by migrating birds may impose a collision hazard, which to some extent may be counteracted by the capability of avoidance for each species. It is also important to note that often passerines are amongst the dominant species groups associated with collision events at night (Newton 2007).

We have made no attempt to estimate the number of collisions between nocturnal migrants and turbines and masts at the test centre. However, on the basis of the general assumption that the test centre is not situated on a migration corridor, although some seasonal migration takes place, we consider the number of collisions to be limited.

The result from the carcass searches supports this reasoning, although it should be mentioned that smaller passerines are more likely to be scavenged or go undetected during searches.

In general, passerines are suggested to be among the bird species least susceptible to additional mortality from wind turbines and other structures. In addition, Erickson et al. (2005) point to the fact that even for nocturnal migrants global collision estimates clearly indicate that the numbers of casualties at wind farms are at least three orders of magnitudes lower than the numbers killed by collisions with buildings, power lines and air fields. Therefore, for this intermediate assessment, we consider the potential impact of the combined structures at the test centre on nocturnal migrants, which are expected to be dominated by smaller passerines, to be small.

# Evaluation of cumulative impacts

We use the term "cumulative impact" as stated in the EU-guidelines for undertaking impact assessments (Walker & Johnston 1999). Here cumulative impacts are defined as "Impacts that result from incremental changes caused by other past, present or reasonably foreseeable actions together with the project". Hence, a proper assessment of the cumulative impact imposed by the Østerild Test Centre on the bird populations necessitates that reliable estimates of the number of collisions or indirect effects causing additional mortality or reduced reproductive output have been predicted for other wind farms and other sources of man-induced mortality. Ideally all species on the various annexes of the EC-Birds Directive, vulnerable species, and all species with reproductive low output should be included in an assessment of the cumulative impact (King et al. 2009, Masden et al. 2010).

In the baseline report we provided an analysis for the species or species groups (individuals or stages of the annual life cycle), which were most likely affected should any adverse effect occur (sensu Masden et al. 2010). The list of recommended species was preliminary to allow for other species to be added as new knowledge emerges from the post-construction studies.

The list comprised light-bellied brent geese, taiga bean goose, pink-footed goose, common crane, golden plover and day and night-migrating passerines.

The intermediate assessment of individual species and species groups, which has been presented above, confirmed the results of the baseline study that the potential impact of the combined structures on the birds occurring in the study area are unlikely to be significant. Therefore, no new species have been added to the list of recommended species for particular study.

In the final post-construction report we will provide a revised assessment of the cumulative impact of the test centre on the relevant species. For now, we refer to the evaluation presented in the baseline report pages 113-116 (Therkildsen et al. 2012).

# Conclusions and perspectives

In the baseline report (Therkildsen et al. 2012) we presented the first species-specific study of the bird migration in the Østerild area. A preliminary assessment of the potential impact of the test centre on four focal species, for which SPAs have been designated in the vicinity of the test centre, was carried out. These species were whooper swan, pink-footed goose, taiga bean goose and common crane. In addition, a number of species were included in the preliminary assessment on the basis of their regular occurrence in the study area. In the baseline report we also presented the results of the first study of broad front nocturnal migration in this part of Denmark.

This report presents the results of the first post-construction study year. In addition to the four focal species included in the baseline study, we included white-tailed eagle and light-bellied brent goose as focal species on the basis of their conservation status and their occurrence in the study area.

The amount of field work during the post-construction study was increased markedly. Therefore, more data were collected, which enabled us to perform a more robust analysis of the potential impacts of the test centre on the bird species occurring in the study area.

In addition, we conducted searches by dogs to provide data on fatalities from collisions with wind turbines, met and aviation masts. Likewise, we carried out transect counts to investigate whether, and to what extent, nightjars occurred in the study area during the breeding season.

In general, the post-construction study supported the conclusions made from the baseline study. We confirmed that the test centre is not situated on a migration corridor, although seasonal migration took place to some extent, particularly during night. During the day, flight activity in the study area was dominated by local birds moving between feeding areas and night roosts in northwest Jutland, some of which has been designated as SPAs for the species included in the study. Regular movements of local birds that may be breeding, staging or wintering can lead to a higher number of passages of an area compared to seasonal migration, when migrants pass through an area once or twice a year (Kahlert et al. 2010). Indeed, as was the case during the baseline study, we demonstrated local movements to take place on a regular basis for a number of species.

In the baseline study, the species for which we estimated that more than one annual collision with wind turbines would take place were cormorant (3), pink-footed goose (21-46), greylag goose (3-6) and golden plover (65).

In the post-construction study, we estimated that more than one annual collision with wind turbines would take place for cormorant (6-14), pink-footed goose (10-23), greylag goose (23-52), buzzard (0.8-1.6), golden plover (3-7), wood pigeon (0.5-1.2) and passerines (3-5).

However, despite the high proportion of individuals of these species passing the study area at rotor height, only very limited numbers of collisions were predicted. It is also important to notice that in contrast to the baseline study, the post-construction study period covered the whole annual cycle, except for June-July.

For the remainder of the species that regularly occur in the study area, including the focal species whooper swan, taiga bean goose, common crane, light bellied brent goose and white-tailed eagle, we predicted that the annual number of collisions would be less than one. This was typically a result of a high proportion of individuals and flocks migrating at flight altitudes below the rotor height of the wind turbines.

Five territories of nightjars were registered on the basis of the presence of advertising males in July 2014. We were unable to estimate the collision risk between turbines and nightjars and therefore the assessment of potential negative impacts at the local breeding population awaits further studies. This issue will therefore be addressed in the second post-construction study year.

On the basis of this intermediate assessment, which uses more reliable estimates of collision risk than those obtained during the baseline study, we still consider that the potential impacts of the combined structures on the bird species occurring in the study area are unlikely to be significant. We stress that our crude estimates of the number of collisions should be interpreted with caution including comparison of collision estimates between the two study periods.

Since the test centre had only four turbines in operation during the post-construction study period, the assessment do not consider a fully developed test centre, which may have up to seven turbines simultaneously in operation. The presence of more turbines may affect flight behaviour and migration pathways on both small and large spatial scales, which may potentially affect the risk of collisions with turbines and other structures. Therefore the calculated number of collisions must be regarded as a crude estimate, which means that the potential impact of the test centre on bird species may be somewhat underestimated. However, this does not affect the conclusion that the overall impact of the test centre on bird species is considered unlikely to be significant.

Although no fatalities were retrieved during the carcass searches, we consider the complete absence of collisions between birds and the structures at the test centre to be highly unlikely. We therefore assume that either some fatalities were missed by, or were not available to the dogs or they were removed by scavengers between searches. Nevertheless, the results of the carcass searches indicate that the number of collisions is probably rather small. The result of the carcass searches therefore supports our conclusion that collisions with turbines and other structures at the test centre are to be expected, but at a low rate.

It is important to keep in mind that the data collected during the baseline and the post-construction programmes only covers less than two years. We are therefore cautious when we assess the extent to which there may be year-to-year variation in the occurrence of birds both during night and day. In particular, different weather conditions can affect flight behaviour and migration pathways on both small and large scales.

The use of standardized methods during our investigations will allow us to continue the collection of species-specific data during the final part of the post-construction programme to further improve the level of detail in the final impact assessment of the test centre on relevant bird populations. Therefore the post-construction programme will continue to focus on periods when species of potential concern occur in the study area. In particular, we will focus on obtaining data on the behaviour and occurrence of nightjars, an Annex 1 species of the EC Birds Directive, which may potentially be foraging in close proximity to the turbines.

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# Appendices and Tables

## Appendix B1

The list contains all species registered during the post-construction studies. The number of passages represents all observations of an individual or a flock on transect counts. The number of individuals represent the total number of individuals registered on transects. The number of measurements obtained using laser ranger finder includes sequential measurements of the same individual or flock.

| | | | Transects | | Laser range finder |
|---|---|---|---|---|---|
| **Species name** | **Scientific name** | **Danish name** | **Passages** | **Individuals** | **Measurements** |
| Barn swallow | Hirundo rustica | Landsvale | 177 | 1039 | 40 |
| Barnacle goose | Branta leucopsis | Bramgås | 6 | 153 | 7 |
| Blackbird | Turdus merula | Solsort | 2 | 2 | 0 |
| Bohemian waxwing | Bombycilla garrulus | Silkehale | 1 | 3 | 1 |
| Brambling | Fringilla montifringilla | Kvækerfinke | 3 | 15 | 0 |
| Buzzard | Buteo buteo | Musvåge | 231 | 258 | 1494 |
| Carrion crow | Corvus corone | Sortkrage | 18 | 18 | 10 |
| Collared dove | Streptopelia decaocto | Tyrkerdue | 2 | 5 | 0 |
| Common black-headed gull | Chroicocephalus ridibundus | Hættemåge | 56 | 145 | 33 |
| Common chaffinch | Fringilla coelebs | Bogfinke | 24 | 310 | 3 |
| Common crane | Grus grus | Trane | 24 | 60 | 219 |
| Common cuckoo | Cuculus canorus | Gøg | 4 | 6 | 7 |
| Common greenshank | Tringa nebularia | Hvidklire | 2 | 2 | 3 |
| Common house martin | Delichon urbicum | Bysvale | 2 | 3 | 4 |
| Common merganser | Mergus merganser | Stor skallesluger | 0 | 0 | 1 |
| Common raven | Corvus corax | Ravn | 27 | 38 | 104 |
| Common redshank | Tringa totanus | Rødben | 0 | 0 | 1 |
| Common ringed plover | Charadrius hiaticula | Stor præstekrave | 0 | 0 | 3 |
| Common shelduck | Tadorna tadorna | Gravand | 16 | 29 | 68 |
| Common snipe | Gallinago gallinago | Dobbeltbekkasin | 9 | 30 | 8 |
| Common starling | Sturnus vulgaris | Stær | 108 | 3848 | 89 |
| Common swift | Apus apus | Mursejler | 1 | 1 | 4 |
| Common tern | Sterna hirundo | Fjordterne | 1 | 1 | 8 |
| Cormorant | Phalacrocorax carbo | Skarv | 662 | 3293 | 2255 |
| Corn bunting | Emberiza calandra | Bomlærke | 9 | 118 | 8 |
| Crossbill | Loxia sp. | Korsnæb | 1 | 9 | 0 |
| Curlew | Numenius arquata | Stor regnspove | 1 | 1 | 13 |

| | | | | | |
|---|---|---|---|---|---|
| Egyptian goose | Alopochen aegyptiaca | Nilgås | 0 | 0 | 4 |
| Eurasian bullfinch | Pyrrhula pyrrhula | Dompap | 1 | 1 | 0 |
| Eurasian magpie | Pica pica | Husskade | 28 | 35 | 23 |
| Eurasian siskin | Carduelis spinus | Grønsisken | 0 | 0 | 1 |
| Eurasian sparrowhawk | Accipiter nisus | Spurvehøg | 15 | 15 | 51 |
| Eurasian teal | Anas crecca | Krikand | 2 | 45 | 1 |
| European greenfinch | Carduelis chloris | Grønirisk | 3 | 8 | 3 |
| European honey-buzzard | Pernis apivorus | Hvepsevåge | 2 | 2 | 5 |
| Fieldfare | Turdus pilaris | Sjagger | 18 | 876 | 37 |
| Golden plover | Pluvialis apricaria | Hjejle | 23 | 3055 | 23 |
| Goldfinch | Carduelis carduelis | Stillits | 4 | 6 | 1 |
| Great black-backed gull | Larus marinus | Svartbag | 65 | 153 | 160 |
| Great grey shrike | Lanius excubitor | Stor tornskade | 1 | 1 | 9 |
| Great spotted woodpecker | Dendrocopos major | Stor flagspætte | 3 | 4 | 3 |
| Green sandpiper | Tringa ochropus | Svaleklire | 1 | 1 | 1 |
| Grey heron | Ardea cinerea | Fiskehejre | 32 | 36 | 201 |
| Greylag goose | Anser anser | Grågås | 304 | 11273 | 991 |
| Hen harrier | Circus cyaneus | Blå kærhøg | 12 | 12 | 54 |
| Herring gull | Larus argentatus | Sølvmåge | 154 | 526 | 337 |
| Hooded crow | Corvus cornix | Gråkrage | 281 | 556 | 387 |
| House sparrow | Passer domesticus | Gråspurv | 1 | 1 | 0 |
| Jackdaw | Corvus monedula | Allike | 31 | 183 | 21 |
| Jay | Garrulus glandarius | Skovskade | 5 | 7 | 1 |
| Kestrel | Falco tinnunculus | Tårnfalk | 102 | 113 | 430 |
| Lapland longspur | Calcarius lapponicus | Laplandsværling | 1 | 1 | 0 |
| Lapwing | Vanellus vanellus | Vibe | 30 | 641 | 112 |
| Lesser black-backed gull | Larus fuscus | Sildemåge | 7 | 19 | 30 |
| Lesser/Common redpoll | Carduelis cabaret/flammea | Lille/stor gråsisken | 19 | 164 | 11 |
| Light-bellied brent goose | Branta bernicla hrota | Lysbuget knortegås | 0 | 0 | 1 |
| Linnet | Carduelis cannabina | Tornirisk | 3 | 11 | 0 |
| Mallard | Anas platyrhynchos | Gråand | 18 | 127 | 35 |
| Marsh harrier | Circus aeruginosus | Rørhøg | 46 | 46 | 296 |
| Meadow pipit | Anthus pratensis | Engpiber | 21 | 73 | 5 |
| Merlin | Falco columbarius | Dværgfalk | 5 | 5 | 8 |
| Mew gull | Larus canus | Stormmåge | 6 | 79 | 30 |
| Mistle thrush | Turdus viscivorus | Misteldrossel | 3 | 11 | 0 |
| Montagu's/Pallid harrier | Circus pygargus/macrourus | Hede-/Steppehøg | 0 | 0 | 1 |
| Mute swan | Cygnus olor | Knopsvane | 2 | 4 | 9 |
| Northern goshawk | Accipiter gentilis | Duehøg | 3 | 3 | 7 |
| Osprey | Pandion haliaetus | Fiskeørn | 1 | 1 | 11 |
| Parrot crossbill | Loxia pytyopsittacus | Stor korsnæb | 5 | 25 | 6 |
| Peregrine falcon | Falco peregrinus | Vandrefalk | 12 | 13 | 76 |
| Pink-footed goose | Anser brachyrhynchus | Kortnæbbet gås | 106 | 9782 | 419 |

| | | | | | |
|---|---|---|---|---|---|
| Red crossbill | Loxia curvirostra | Lille korsnæb | 11 | 85 | 10 |
| Red kite | Milvus milvus | Rød glente | 2 | 2 | 11 |
| Redwing | Turdus iliacus | Vindrossel | 1 | 1 | 0 |
| Reed bunting | Emberiza schoeniclus | Rørspurv | 16 | 39 | 5 |
| Richard's pipit | Anthus richardi | Storpiber | 0 | 0 | 1 |
| Ring ouzel | Turdus torquatus | Ringdrossel | 5 | 21 | 7 |
| Rook | Corvus frugilegus | Råge | 0 | 0 | 4 |
| Rough-legged buzzard | Buteo lagopus | Fjeldvåge | 4 | 4 | 57 |
| Sand martin | Riparia riparia | Digesvale | 6 | 226 | 3 |
| Skylark | Alauda arvensis | Sanglærke | 28 | 86 | 73 |
| Snow bunting | Plectrophenax nivalis | Snespurv | 2 | 5 | 2 |
| Song thrush | Turdus philomelos | Sangdrossel | 0 | 0 | 2 |
| Wheatear | Oenanthe oenanthe | Stenpikker | 2 | 2 | 1 |
| Stock dove | Columba oenas | Huldue | 1 | 2 | 0 |
| Taiga bean goose | Anser fabalis fabalis | Skovsædgås | 10 | 73 | 243 |
| Tree pipit | Anthus trivialis | Skovpiber | 1 | 1 | 2 |
| Tree sparrow | Passer montanus | Skovspurv | 1 | 1 | 1 |
| Tundra swan | Cygnus columbianus | Pibesvane | 3 | 18 | 24 |
| Twite | Carduelis flavirostris | Bjergirisk | 1 | 4 | 0 |
| Two-barred crossbill | Loxia leucoptera | Hvidvinget korsnæb | 1 | 1 | 1 |
| White wagtail | Motacilla alba | Hvid vipstjert | 13 | 16 | 5 |
| White-tailed eagle | Haliaeetus albicilla | Havørn | 36 | 40 | 386 |
| Whitethroat | Sylvia communis | Tornsanger | 1 | 1 | 0 |
| Whooper swan | Cygnus cygnus | Sangsvane | 50 | 241 | 330 |
| Wood pigeon | Columba palumbus | Ringdue | 329 | 911 | 220 |
| Woodcock | Scolopax rusticola | Skovsneppe | 1 | 1 | 0 |
| Yellow wagtail | Motacilla flava | Gul vipstjert | 1 | 1 | 2 |
| Yellowhammer | Emberiza citrinella | Gulspurv | 61 | 378 | 13 |

## Appendix B2

In order to estimate the theoretical annual number of collisions at the Østerild Test Centre the so-called "Band-model" (Band 2000) was applied. The Band-model did not originally incorporate avoidance responses. However, given the importance of this factor, the model was extended with this factor. The number of collisions ($C_{tot}$) can be calculated as:

$C_{tot} = N_{bird} * P_a * P_{na},$

where $N_{bird}$ = number of bird transits through the rotor, $P_a$ = probability of avoidance and $P_{na}$ = probability of bird flying through rotor showing no avoidance being hit.

### Calculation of $N_{bird}$

The first approach was applied on species with a predictable flight pattern (modified description after Band (2000) given that good data on flight altitude of birds are available):

1. Identify a 'risk window' i.e. a window of width equal to the width of the windfarm across the general flight direction of the birds, and of height of the rotor. The cross-sectional area at rotor height W = width x height.

2. Estimate the number of birds n flying through this risk window per annum, i.e. numbers crossing the row of turbines ($n_{cros}$) x proportion flying at the altitude of the risk window ($p_{risk}$). $n_{cros}$ was calculated as the total number of birds observed on the transects multiplied by the proportion of birds that were likely to occur between the observation station and the northernmost (1,550 m) and southernmost (2,150 m) turbine location. This proportion was derived from the distance measurements with the laser range finder. As the calculation was done on a monthly basis, the ratio between total time of daylight per month and observation time per month was multiplied by the numbers occurring between the northernmost and southernmost turbines per month as calculated above in order to extrapolate from the actual observation periods to the entire month (only daylight periods). $p_{risk}$ was derived from the measurements of flight altitude obtained by laser range finder.

3. Calculate the area A presented by the wind farm rotors. Assume the rotors are aligned in the plane of the risk window as, to a first approximation, any reduction in cross-sectional area because the rotors are at an oblique angle is offset by the increased risk to birds which have to make a longer transit through the rotors.

   A = N x $\pi R^2$ where N is the number of rotors and R is the rotor radius.

4. Express the total rotor area as a proportion A / W of the risk window.

5. Number of birds passing through rotors ($N_{bird}$) = number of birds through risk window x proportion occupied by rotors = n x (A / W).

The second approach is most appropriate for birds such as raptors which occupy a recognized territory, and where observations have led to some understanding of the likely distribution of flights within this territory.

1. Identify a 'flight risk volume' Vw which is the area of the wind farm multiplied by the height of the rotors.

2. Calculate the combined volume swept out by the wind farm rotors Vr = N x $\pi R^2$ x (d + l ) where N is the number of wind turbines, d is the depth of the rotor back to front, and l is the length of the bird.

3. Estimate the bird occupancy n within the flight risk volume. This is the number of birds present multiplied by the proportion of birds occurring at the altitude of the flight risk volume multiplied by the time spent flying in the flight risk volume.

4. The bird occupancy of the volume swept by the rotors is then n x ( Vr / Vw ) bird-secs.

5. Calculate the time taken for a bird to make a transit through the rotor and completely clear the rotors: t = (d + l ) / v where v m/sec is the speed of the bird through the rotor.

6. To calculate the number of bird transits through the rotors, divide the total occupancy of the volume swept by the rotors in bird-secs by the transit time t: Number of birds passing through rotors ($N_{bird}$) = n x ( Vr / Vw ) / t.

#### Calculation of $P_a$

Little information exists on specific avoidance rates from field studies, and hence most avoidance rates (see table below) were based on the recommendations of Scottish Natural Heritage (Urquhart 2010).

| Species | Avoidance rate (%) |
|---|---|
| Cormorant | 97.75-99.00 |
| Whooper swan | 97.75-99.00 |
| Tundra swan | 97.75-99.00 |
| Pink-footed goose | 97.75-99.00 |
| Taiga bean goose | 97.75-99.00 |
| Greylag goose | 97.75-99.00 |
| Marsh harrier | 98.00-99.00 |
| Hen harrier | 98.00-99.00 |
| Buzzard | 98.00-99.00 |
| White-tailed eagle | 97.75-99.00 |
| Kestrel | 98.00-99.00 |
| Peregrine falcon | 98.00-99.00 |
| Common crane | 97.75-99.00 |
| Golden plover | 97.75-99.00 |
| Wood pigeon | 97.75-99.00 |
| Common raven | 98.00-99.00 |
| Passerines | 98.00-99.00 |

#### Calculation of $P_{na}$

The computation of the probability of birds being hit when passing rotors is complex and involves many factors. The approach was again taken from the Band model (below a modified description after Band (2000)).

The probability depends on the size of the bird (both length and wingspan), the breadth and pitch of the turbine blades, the rotation speed of the turbine, and of course the flight speed of the bird. To facilitate calculation, many simplifications have to be made. The bird is assumed to be of simple cruciform shape, with the wings at the halfway point between bill and tail. The turbine blade is assumed to have a width and a pitch angle (relative to the plane of the turbine), but to have no thickness. Each blade cuts a swathe through the air which depends both on the breadth of the blade and its pitch angle. Successive blades cut parallel swathes, but progressively closer to the bird. The angle of approach of the blade α depends on both bird speed and blade speed. At the rotor extremity, where blade speed is usually high compared to bird speed, the approach angle α is low, i.e. the blades approach the bird from the side. Close to the rotor hub, where the blade speed is low and the bird is therefore flying towards a slow-moving object, the approach angle α is high. The probability of bird collision, for given bird and blade dimensions and speeds, is the probability, were the bird placed anywhere at random on the line of flight, of it overlapping with a blade swathe (since the bird, in this frame, is stationary). It may therefore be calculated from simple geometric considerations. Where the angle of approach is shallow, it is the length of the bird, compared to the separation distance of successive swathes, which is the controlling factor. Where the angle of approach is high, it is the wingspan of the bird compared to the physical distance between blades, which is the controlling factor.

The calculation derives a probability $p(r, \phi)$ of collision for a bird at a radius r from the hub, and at a position along a radial line which is an angle $\phi$ from the vertical. It is then necessary to integrate this probability over the entire rotor disc, assuming that the bird transit may be anywhere at random within the area of the rotor disc:

Total probability = $(1/\pi R^2) \iint p(r, \phi)\, r\, dr\, d\phi = 2\int p(r)\,(r/R)\, d(r/R)$ (1),

where p(r) now allows for the integration over $\phi$.

Probability p of collision for a bird at a radius r from hub, l for $\alpha < \beta$

$p(r) = ( b\Omega/2\pi v ) [ K \mid \pm c \sin\gamma + \alpha c \cos\gamma \mid + ]\, w\alpha F$ for $\alpha > \beta$ (2),

where b = number of blades in rotor, $\Omega$ = angular velocity of rotor (radians/sec), c = chord width of blade

$\gamma$ = pitch angle of blade, R = outer rotor radius, l = length of bird, w = wingspan of bird, $\beta$ = aspect ratio of bird i.e. l / w, v = velocity of bird through rotor, r = radius of point of passage of bird, $\alpha = v/r\Omega$, F = 1 for a bird with flapping wings (no dependence on $\phi$) = $(2/\pi)$ for a gliding bird, K = 0 for one-dimensional model (rotor with no zero chord width) K = 1 for three-dimensional model (rotor with real chord width).

The chord width of the blade c and the blade pitch $\gamma$, i.e. the angle of the blade relative to the rotor plane, vary from rotor hub to rotor tip. The chord width is typically greatest close to the hub and the blade tapers towards the tip. The pitch is shallowest close to the tip where the blade speed is highest. The apparent width of the blade, looked at from the front, is $c \cos\gamma$, and the depth of blade from back to front is $c \sin\gamma$.

The factor F is included to cover the two extreme cases where the bird has flapping wings ($p(r, \phi)$ has no dependence on $\phi$) or is gliding ($p(r, \phi)$ is $\phi$ dependent, i.e. at maximum above and below hub, at minimum when wings are parallel with rotor blade). F=1 for flapping bird, F = $2/\pi$ for a gliding bird. The sign of the $c \sin\gamma$ term depends on whether the flight is upwind (+) or downwind (-). The factor K is included to give a simple option of checking the effect of real blade width in the result: K=0 models a one-dimensional blade with no chord width. As $\alpha$, c and $\gamma$ all vary between hub and rotor tip, a numerical integration is easiest when evaluating equation (1).

For ease of use these calculations are laid out on spreadsheet available at http://www.snh.gov.uk/docs/C234672.xls. The spreadsheet calculates p(r) at intervals of 0.05 R from the rotor centre (i.e. evaluating equation (2)), and then undertakes a numerical integration from r=0 to r=R (i.e. evaluating equation (1).

In a real case it may be important to add in the effect of wind to the bird's ground speed, and flight patterns may not be such that upwind and downwind flights are equally frequent. The result is an average collision risk for a bird passing through a rotor. Note that there are many approximations involved, for example in assuming that a bird can be modelled by a simple cruciform shape, that a turbine blade has width and pitch but no thickness, and that a bird's flight will be unaffected by a near miss, despite the slip-stream around a turbine blade. Thus the calculated collision risks should be held as an indication of the risk - say to around ±10%, rather than an exact figure. It is also simplistic to assume that bird flight velocity is likely to be the same relative to the ground both upwind and downwind. Ideally, separate calculations should be done for the upwind and downwind case, using typical observed flight speeds.

In the present case the length of the bird species and wingspan were derived from DOFbasen (www.dofbasen.dk/art), while flight speeds were mainly obtained from Alerstam et al. (2007).

| Species | Body length (m) | Wing span (m) | Flight speed (m/s) |
|---|---|---|---|
| Greylag goose | 0.80 | 1.63 | 17.1 |
| Pink-footed goose | 0.68 | 1.53 | 16.1 |
| Taiga bean goose | 0.67 | 1.61 | 17.3 |
| Common crane | 1.15 | 2.15 | 14.9 |
| Golden plover | 0.27 | 0.72 | 13.7 |
| Tundra swan | 1.22 | 1.96 | 18.5 |
| Whooper swan | 1.52 | 2.31 | 17.3 |
| Cormorant | 0.9 | 1.45 | 15.2 |
| Peregrine falcon | 0.4 | 1.05 | 12.1 |
| Kestrel | 0.34 | 0.7 | 12.1 |
| Marsh harrier | 0.5 | 1.3 | 9.1 |
| White-tailed eagle | 0.9 | 2.3 | 13.0 |
| Hen harrier | 0.47 | 1.10 | 9.1 |
| Buzzard | 0.54 | 1.21 | 12.5 |
| Wood pigeon | 0.41 | 0.78 | 17.0 |
| Common raven | 0.64 | 1.35 | 14.3 |
| Passerines | 0.24 | 0.34 | 13.0 |

The technical specifications of the turbines, which were incorporated in the model in the present case, are presented in the table below.

| Wind turbine type | Vestas V126 | Vestas V164 | Siemens SWT 4.0-130 | Siemens SWT 6.0-154 |
|---|---|---|---|---|
| Period | Throughout the period | From January 2014 | Until May 2014 | Throughout |
| Hub height (m) | 116 | 140 | 110 | 120 |
| Rotor altitude (m) | 53-179 | 58-222 | 45 -175 | 43 - 197 |
| Rotor diameter (m) | 126 | 164 | 130 | 154 |
| Time per rotation (sec) | 3.6 - 11.3 | 4.39 - 9.2 | 4.48 | 5.45 |
| Wing breadth (m) | 4 | 5.4 | 4.1 | 6 |

**Table B1.**

General linear model on altitude in relation to distance to wind turbines, baseline-vs-post-construction, wind speed, month and the interaction between distance to wind turbines and baseline-vs-post-construction.

| Species | Source | DF | df error | F Value | Prob F |
|---|---|---|---|---|---|
| Hen harrier | model | 12 | 37 | 2.795088 | 0.00815 |
| Hen harrier | baseline-vs-post-construction | 1 | 37 | 2.389027 | 0.130701 |
| Hen harrier | month | 8 | 37 | 1.090404 | 0.391426 |
| Hen harrier | distance | 1 | 37 | 26.8635 | 8E-06 |
| Hen harrier | distance*baseline-vs-post-construction | 1 | 37 | 4.85224 | 0.03392 |
| Hen harrier | wind speed | 1 | 37 | 1.144219 | 0.291691 |
| White-tailed eagle | model | 14 | 429 | 8.960967 | 2.8E-17 |
| White-tailed eagle | baseline-vs-post-construction | 1 | 429 | 4.510416 | 0.03426 |
| White-tailed eagle | month | 10 | 429 | 10.40889 | 8.4E-16 |
| White-tailed eagle | distance | 1 | 429 | 2.970446 | 0.085519 |
| White-tailed eagle | distance*Baseline-vs-post-construction | 1 | 429 | 0.033903 | 0.854001 |
| White-tailed eagle | wind speed | 1 | 429 | 2.428873 | 0.119856 |
| White-tailed eagle | model | 12 | 74 | 1.973417 | 0.03887 |
| White-tailed eagle | baseline-vs-post-construction | 0 | 74 | | |
| White-tailed eagle | month | 10 | 74 | 1.431644 | 0.183472 |
| White-tailed eagle | distance | 1 | 74 | 0.042121 | 0.837953 |
| White-tailed eagle | distance*baseline-vs-post-construction | 0 | 74 | | |
| White-tailed eagle | wind speed | 1 | 74 | 2.205028 | 0.141809 |
| Golden plover | model | 10 | 32 | 0.504089 | 0.874375 |
| Golden plover | baseline-vs-post-construction | 1 | 32 | 1.371206 | 0.250251 |
| Golden plover | month | 6 | 32 | 0.190698 | 0.977235 |
| Golden plover | distance | 1 | 32 | 0.481402 | 0.492794 |
| Golden plover | distance*baseline-vs-post-construction | 1 | 32 | 1.044342 | 0.314478 |
| Golden plover | wind speed | 1 | 32 | 0.703212 | 0.407927 |
| Pink-footed goose | model | 11 | 331 | 9.801335 | 2.1E-15 |
| Pink-footed goose | baseline-vs-post-construction | 1 | 331 | 2.260593 | 0.133657 |
| Pink-footed goose | month | 7 | 331 | 7.765276 | 1.1E-08 |
| Pink-footed goose | distance | 1 | 331 | 5.939023 | 0.01534 |
| Pink-footed goose | distance*baseline-vs-post-construction | 1 | 331 | 3.776869 | 0.052813 |
| Pink-footed goose | wind speed | 1 | 331 | 2.404052 | 0.121977 |
| Buzzard | model | 14 | 784 | 7.034278 | 8.4E-14 |
| Buzzard | baseline-vs-post-construction | 1 | 784 | 0.447347 | 0.503794 |
| Buzzard | month | 10 | 784 | 5.708722 | 2.7E-08 |
| Buzzard | distance | 1 | 784 | 0.280066 | 0.596808 |
| Buzzard | distance*baseline-vs-post-construction | 1 | 784 | 0.479165 | 0.489006 |
| Buzzard | wind speed | 1 | 784 | 12.95392 | 0.00034 |
| Tundra swan | model | 5 | 8 | 1.088704 | 0.434529 |
| Tundra swan | baseline-vs-post-construction | 0 | 8 | | |
| Tundra swan | month | 3 | 8 | 1.499346 | 0.287045 |
| Tundra swan | distance | 1 | 8 | 0.079218 | 0.785504 |
| Tundra swan | distance*baseline-vs-post-construction | 0 | 8 | | |
| Tundra swan | wind speed | 1 | 8 | 2.298246 | 0.16799 |

| | | | | | |
|---|---|---|---|---|---|
| Common raven | model | 13 | 64 | 0.942998 | 0.5155 |
| Common raven | baseline-vs-post-construction | 1 | 64 | 0.968682 | 0.328715 |
| Common raven | month | 9 | 64 | 0.631419 | 0.766015 |
| Common raven | distance | 1 | 64 | 0.065459 | 0.798888 |
| Common raven | distance*baseline-vs-post-construction | 1 | 64 | 0.113473 | 0.737327 |
| Common raven | wind speed | 1 | 64 | 1.121145 | 0.293652 |
| Wood pigeon | model | 13 | 260 | 2.676067 | 0.00152 |
| Wood pigeon | baseline-vs-post-construction | 1 | 260 | 0.411419 | 0.521815 |
| Wood pigeon | month | 9 | 260 | 2.500006 | 0.00931 |
| Wood pigeon | distance | 1 | 260 | 1.863507 | 0.173401 |
| Wood pigeon | distance*baseline-vs-post-construction | 1 | 260 | 0.880364 | 0.348973 |
| Wood pigeon | wind speed | 1 | 260 | 0.721132 | 0.396554 |
| Marsh harrier | model | 9 | 87 | 0.321131 | 0.966009 |
| Marsh harrier | baseline-vs-post-construction | 1 | 87 | 0.000508 | 0.982071 |
| Marsh harrier | month | 5 | 87 | 0.47186 | 0.796281 |
| Marsh harrier | distance | 1 | 87 | 0.006988 | 0.93357 |
| Marsh harrier | distance*baseline-vs-post-construction | 1 | 87 | 0.005313 | 0.94206 |
| Marsh harrier | wind speed | 1 | 87 | 0.141049 | 0.708154 |
| Taiga bean goose | model | 10 | 105 | 7.189271 | 1.5E-08 |
| Taiga bean goose | baseline-vs-post-construction | 1 | 105 | 0.565697 | 0.453656 |
| Taiga bean goose | month | 6 | 105 | 7.652044 | 7.9E-07 |
| Taiga bean goose | distance | 1 | 105 | 4.44349 | 0.03741 |
| Taiga bean goose | distance*baseline-vs-post-construction | 1 | 105 | 5.048515 | 0.02674 |
| Taiga bean goose | wind speed | 1 | 105 | 12.54029 | 0.0006 |
| Whooper swan | model | 9 | 337 | 3.105691 | 0.00133 |
| Whooper swan | baseline-vs-post-construction | 1 | 337 | 2.83E-06 | 0.998659 |
| Whooper swan | month | 5 | 337 | 4.545335 | 0.0005 |
| Whooper swan | distance | 1 | 337 | 1.085226 | 0.298278 |
| Whooper swan | distance*baseline-vs-post-construction | 1 | 337 | 0.037053 | 0.847472 |
| Whooper swan | wind speed | 1 | 337 | 2.070772 | 0.151074 |
| Cormorant | model | 14 | 1018 | 2.38573 | 0.00283 |
| Cormorant | baseline-vs-post-construction | 1 | 1018 | 6.871334 | 0.00889 |
| Cormorant | month | 10 | 1018 | 2.335538 | 0.01009 |
| Cormorant | distance | 1 | 1018 | 1.773939 | 0.183193 |
| Cormorant | distance*baseline-vs-post-construction | 1 | 1018 | 6.122804 | 0.01351 |
| Cormorant | wind speed | 1 | 1018 | 0.086874 | 0.768249 |
| Kestrel | model | 11 | 240 | 1.618026 | 0.094251 |
| Kestrel | baseline-vs-post-construction | 1 | 240 | 0.3874 | 0.53426 |
| Kestrel | month | 7 | 240 | 0.611625 | 0.746115 |
| Kestrel | distance | 1 | 240 | 5.174777 | 0.0238 |
| Kestrel | distance*baseline-vs-post-construction | 1 | 240 | 2.379884 | 0.124224 |
| Kestrel | wind speed | 1 | 240 | 4.207339 | 0.04134 |
| Common crane | model | 13 | 97 | 3.773584 | 6.9E-05 |
| Common crane | baseline-vs-post-construction | 1 | 97 | 2.43329 | 0.12204 |
| Common crane | month | 9 | 97 | 4.39342 | 7.9E-05 |
| Common crane | distance | 1 | 97 | 6.119205 | 0.01511 |
| Common crane | distance*baseline-vs-post-construction | 1 | 97 | 1.13579 | 0.289189 |
| Common crane | wind speed | 1 | 97 | 1.914441 | 0.169647 |
| Peregrine falcon | model | 11 | 23 | 3.255082 | 0.00818 |
| Peregrine falcon | baseline-vs-post-construction | 1 | 23 | 0.037371 | 0.848408 |
| Peregrine falcon | month | 7 | 23 | 1.444995 | 0.23588 |
| Peregrine falcon | distance | 1 | 23 | 9.471233 | 0.00532 |
| Peregrine falcon | distance*baseline-vs-post-construction | 1 | 23 | 11.0447 | 0.00296 |
| Peregrine falcon | wind speed | 1 | 23 | 0.017714 | 0.895276 |

### Table B2

Slope estimates for regressions on altitude in relation to minimum distance to the wind turbines by species and baseline-vs-post-construction. Regressions were made on species where the interactions between baseline-vs-post-construction and distance to wind turbines were significant.

| Baseline-vs-post-construction | Species | Dependent | Parameter | Slope estimate | SE | t | P |
|---|---|---|---|---|---|---|---|
| Post-construction | Hen harrier | alt | distance | 0.058022 | 0.013103 | 4.428081 | 0.000141 |
| Baseline | Hen harrier | alt | distance | 0.028439 | 0.011424 | 2.489337 | 0.022234 |
| Post-construction | Taiga bean goose | alt | distance | -0.01314 | 0.007856 | -1.67205 | 0.098978 |
| Baseline | Taiga bean goose | alt | distance | -0.00639 | 0.007623 | -0.83879 | 0.406335 |
| Post-construction | Cormorant | alt | distance | 0.002769 | 0.003775 | 0.733609 | 0.463412 |
| Baseline | Cormorant | alt | distance | -0.01286 | 0.004914 | -2.61648 | 0.009394 |
| Post-construction | Peregrine falcon | alt | distance | -0.03407 | 0.014159 | -2.4063 | 0.022712 |
| Baseline | Peregrine falcon | alt | distance | 0.152303 | 0.08025 | 1.897852 | 0.130562 |

### Table B3

Least square means estimates for flight altitude for comparisons between baseline and post-construction.

| Species | Baseline | Post-construction |
|---|---|---|
| Greylag goose | 88.88586 | 71.56312 |
| Hen harrier | 11.1849 | 117.1428 |
| Golden plover | 73.92562 | 14.44266 |
| Pink-footed goose | 84.02151 | 47.94037 |
| Buzzard | 50.00592 | 113.4733 |
| Tundra swan | 32.5195 | 62.81068 |
| Common raven | 65.264 | 36.54873 |
| Wood pigeon | 31.89162 | 39.17105 |
| Marsh harrier | 40.69311 | 42.32255 |
| Taiga bean goose | 84.55635 | 78.35686 |
| Whooper swan | 28.73786 | 28.26292 |
| Cormorant | 82.00592 | 76.72586 |
| Kestrel | 32.10941 | 27.32289 |
| Common crane | 38.94706 | 61.55135 |
| Peregrine falcon | 126.7089 | 35.92843 |

**Table B4**

Estimates for effects of distance on flight altitude.

| Species | Estimate | Standard Error | t | P |
|---|---|---|---|---|
| Hen harrier | 0.032133 | 0.010875 | 2.954751 | 0.005416 |
| Greylag goose | -0.0063 | 0.005434 | -1.16003 | 0.246683 |
| White-tailed eagle | -0.00491 | 0.023937 | -0.20523 | 0.837953 |
| Golden plover | -0.00815 | 0.018582 | -0.43877 | 0.663779 |
| Pink-footed goose | 0.002791 | 0.006575 | 0.424501 | 0.671476 |
| Buzzard | -0.00103 | 0.011133 | -0.09285 | 0.926044 |
| Tundra swan | 0.004331 | 0.015386 | 0.281456 | 0.785504 |
| Common raven | 0.010251 | 0.030421 | 0.336969 | 0.737243 |
| Wood pigeon | 0.001818 | 0.007205 | 0.25237 | 0.800955 |
| Marsh harrier | -0.01337 | 0.16997 | -0.07865 | 0.93749 |
| Whooper swan | 0.002857 | 0.002401 | 1.189882 | 0.23493 |
| Cormorant | -0.01203 | 0.004963 | -2.42441 | 0.015507 |
| Taiga bean goose | 0.00069 | 0.005802 | 0.119008 | 0.905496 |
| Common crane | 0.052717 | 0.027454 | 1.920174 | 0.057774 |
| Kestrel | 0.023799 | 0.011211 | 2.122861 | 0.03479 |
| Peregrine falcon | 0.15364 | 0.042449 | 3.619446 | 0.00144 |

# FIRST YEAR POST-CONSTRUCTION MONITORING OF BATS AND BIRDS AT WIND TURBINE TEST CENTRE ØSTERILD

The Department of Bioscience, Aarhus University was commissioned by the Danish Nature Agency to undertake a bat and bird monitoring programme of a national test centre for wind turbines near Østerild in Thy, Denmark. Here we present the results from the first year of the post-construction studies.

Bats were recorded in August, September and October 2013. A total of nine species were recorded. Species composition and occurrence were comparable to the results during summer and autumn 2011. Bats were recorded on 67-85% of survey nights at turbine sites and on every survey night at all ponds and lakes. High activities were recorded throughout the monitoring period at ponds and lakes. Overall, the bat activity level was higher in 2013 than in 2011 at ponds and lakes. Bat activity was higher near the wind turbines than at nearby forest edges. These differences suggest that bats exploit the food resources that accumulate on the turbine towers some nights.

Whooper swan, taiga bean goose, pink-footed goose, common crane, light-bellied brent goose, white-tailed eagle and nightjar were included as focal species in the ornithological investigations. In addition, species specific data on all bird species occurring regularly in the study area were collected. On the basis of an intermediate assessment of collision risk, the potential impacts of the combined structures on the bird species occurring in the study area were considered unlikely to be significant. However, given the uncertainties in the assessment, the post-construction programme will continue to investigate potential impacts on bats and birds.

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