BASELINE INVESTIGATIONS OF BATS AND BIRDS AT WIND TURBINE TEST CENTRE ØSTERILD

Scientific Report from DCE – Danish Centre for Environment and Energy No. 28 2012

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Ole Roland Therkildsen
Morten Elmeros
Johnny Kahlert
Mark Desholm

Aarhus University, Department of Bioscience

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Data sheet

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Editors: Ole Roland Therkildsen, Morten Elmeros, Johnny Kahlert & Mark Desholm
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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 prior to the construction of a national test centre for wind turbines near Østerild in Thy, Denmark. The occurrence and activity level of bats in Østerild Plantation and the vicinity were monitored in summer and autumn 2011. Bats were recorded on 57-100% of surveyed nights at individual wind turbine sites, ponds and lakes. A total of seven species were recorded. Pond bats were recorded at all sites and throughout the survey period in the plantation. Whooper swan, taiga bean goose, pink-footed goose and common crane 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 a preliminary 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 preliminary assessment, the post-construction programme will further investigate potential impacts on bats and birds.

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

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Preface

In June 2010, the Danish Parliament passed a bill that regulates the establishment of a national test centre for large offshore wind turbines in a heath plantation area near Østerild in Thy, NW Denmark. This legislation requires that an environmental monitoring programme should be implemented dealing with the issues of bats, birds and the dune heath habitat in relation to large land-based wind turbines. The following document reports on the first pre-construction year of studies on bats and birds.

The Department of Bioscience, Aarhus University has been contracted to conduct these studies, in collaboration with our sub-contractors Hans Jørgen Baagøe and Julie Dahl Møller (Bats) and Onit.dk (birds), by the Danish National Nature Agency. A steering committee has been established for the project consisting of representatives from Aarhus University, the Danish National Nature Agency and Vindmølle Industrien and the comments from the committee are included in this report.

The main aim of these base-line studies was to elucidate the effect on flying organisms from very high wind turbines (up to 250m). Such huge turbines have never been studied before in this context and the findings will thus be of novel nature. The pre-construction situation described in the present report is then to be compared with the post-construction situation when these high turbines have been installed. Additionally, the results may also, in the future, be used when designing effective mitigation measure if significant conflicts between these man-made structures and the wildlife seem to materialize. Furthermore, the knowledge gained through these investigations may even be used as a final step if it turns out that compensating measures are to be taken if mitigation measures fail.

This report is divided into two separate sections; first the reporting of the bat studies and second the reporting of the bird studies. This approach, in contrary to one fully integrated report including both groups of organisms, was chosen because of the two very different types of methods applied. The types of data collected are very different, and hence, it was decided to present the results on bats and birds separately.

Acknowledgements

We thank Ingemar Ahlén, Sveriges Lantbruksuniversitet for the additional opinions on atypical echolocation bat calls. We also thank Henrik Schjødt Kristensen and Claus Rasmussen, Danish Nature Agency, for assistance in the field and helpful advice. We also thank Bjarne Sønderskov, DTU, Department of Wind Energy for providing information on the technical aspects of turbines and towers.

14 September 2012, Rønde, Denmark

Mark Desholm
Project manager

Summary - bats

Mortality of bats at wind turbines and their effects on the conservation status of bats have received much attention in the planning and operation of wind turbines in most European and North-American countries. Bat mortality rates are affected by the location of wind turbines, the height of the turbines and the wind speed. The mortality of bats is highest at wind turbines located in or near important habitats as forests and wetlands, and on migration routes over land and along the coast. Bat mortality increases with increasing height of wind turbines, and mortality rates are highest on nights with low wind speeds. Bats are killed by the rotating turbine wings. As the reproductive rate of bats is low, the status of bat populations is very sensitive to even small increases in mortality rates.

A national test centre for large wind turbines has been constructed in Østerild Plantation in Denmark. To assess potential effects of the wind turbines on bat occurrence and their use of the test centre area, bats were monitored during summer and autumn 2011 prior to construction work. Bats were monitored with automatic and handheld ultrasound detectors.

Seven species, pond bat (*Myotis dasycneme*), Daubenton's bat (*Myotis daubentonii*), Nathusius' pipistrelle (*Pipistrellus nathusii*), soprano pipistrelle (*Pipistrellus pygmaeus*), serotine bat (*Eptesicus serotinus*), particoloured bat (*Vespertilio murinus*) and brown long-eared bat (*Plecotus auritus*), were recorded at the proposed wind turbine sites, ponds and lakes in the test centre area and its vicinity. Bats occur throughout the area from early July to late October. Bats were recorded on 57-100% of surveyed nights at the individual sites. The number of bat passes was lower along forest roads than at lakes and ponds.

High occurrence and bat activity levels were recorded along forest roads at the southernmost wind turbine sites and at lakes and ponds within the plantation. Lakes, ponds and adjacent forest clearings in the test centre area and its vicinity were used as feeding sites by bats, especially by pond bats and Daubenton's bats. Several individual bats were observed feeding at lakes and ponds. The activity level of pond bats and Daubenton's bats increased at ponds and lakes during autumn.

Extensive feeding activities were recorded at wetland sites in the plantation, and bats are expected to exploit the new feeding habitats in forest clearings at the turbine sites as well as feeding on the insects that congregate at the wind turbines and in the clearings around the turbines. Thus, the highest mortality risk is to be expected at the southernmost wind turbine sites as they are situated in forest and close to wetlands. Future monitoring studies on bat behaviour near wind turbines will focus on these sites.

Summary - birds

In June 2010, the Danish Parliament passed a bill that regulates the establishment of a national test centre for wind turbines near Østerild in Thy, Denmark. This legislation required that an environmental monitoring programme should be implemented.

When fully developed, the test centre will comprise a total of seven test sites for wind turbines (up to 250 m in height). Each test site will consist of a single wind turbine, each with a tower for measuring equipment (up to 150 m in height) located immediately to the west of each turbine. The test centre will also require the construction of illuminated towers supporting meteorological equipment (up to 250 m in height) secured with guy-wires associated with each test site.

The Department of Bioscience, Aarhus University was commissioned by the Danish Nature Agency to undertake a bird monitoring programme in the test area.

Here we present the results of the baseline monitoring programme, which was undertaken in 2011/12 prior to turbine construction 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.

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. Little is known about the seasonal migration and local movements that occur over land at the test centre. However, because of the lack of topographical features to concentrate avian migration, under normal circumstances, we would not expect high densities of migrating birds to be concentrated in or near the test area.

We assumed that daytime local movements accounts for more passages of birds at rotor height within the area than genuine seasonal migration. Therefore, we considered local movement to represent a greater source of potential collisions with wind turbines, although the design of the baseline programme allowed for an assessment of the collision risk associated with both types of migration/movement. 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.

On the basis of a preliminary assessment whooper swan, taiga bean goose, pink-footed goose and common crane were included as focal species in the ornithological investigations. Besides these four species, for which SPAs have been designated in the vicinity of the test centre, the study was designed to obtain species specific data on all bird species occurring regularly in the study area.

During spring 2011, visual transect counts, which have the advantage of providing a detailed quantitative species specific description of bird migration during daytime, were undertaken from a location west of the turbines and measurement towers. At the same time, a horizontally operated radar unit was used to obtain detailed temporal and spatial information on species specific bird movements, as well as information on flight direction. During autumn 2011 and winter 2012, visual counts were carried out from a central observation station, along transects running south and north between the turbine platforms and the measurement towers. Throughout the study period, we used a laser range finder to collect species specific data on flight altitudes of the visible migration during daytime. During night-time, a vertically operated radar unit was used to obtain measurements of flight altitudes and relative migration/movement intensity in the study area. This data collection was based on an automated minute-by-minute screen-dump system that archived the echoes detected by radar. An object-based image analysis was undertaken of the images on the screen and the bird echoes were automatically extracted from screen-dump images by a computer based track recognition procedure.

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. The avoidance rates incorporated in the collision models varied between 97.75 and 99.00% according to species based on the existing literature.

The baseline study confirmed that the test centre is not situated on a migration corridor, although seasonal migration took place to some extent both during night and day. During the day, flight activity in the study area was dominated by local birds moving between feeding areas and night roosts in Northwest Jutland.

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). However, even though these species were all characterized by a high proportion of individuals passing the study area at rotor height, given the overall movement in the area, this only resulted in a relatively limited number of predicted collisions. For the remainder of the species that regularly occur in the study area, including the focal species whooper swan, taiga bean goose and common crane, 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.

In order to provide a crude estimate of the expected number of collisions at the towers, a simple equation was derived from the relationship between tower height and the number of casualties at other study sites. The heights of the towers at the test centre were inserted in the equation and the expected number of casualties at individual towers was multiplied by the number of towers. This resulted in an annual number of casualties of approximately 750 to 1,050 individuals.

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

However, it is important to keep in mind that the data collected during the baseline programme only covers one year. Therefore we are unable to 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. Although the baseline programme covered most of the annual cycle, some important periods were not included in the study. Therefore the post-construction programme will fill out the gaps from the baseline programme by targeting those periods from which little or no current data are available.

By using the data compiled during the baseline programme, the post-construction programme will assess the possible effects and impacts on migrating birds, which may be caused by the operation of the test centre. Particularly, the baseline programme will be used as a reference to assess potential impacts at the population level (mortality caused by collisions) and effects related to behavioural questions (e.g. barrier effects, avoidance of and attraction to the combined structures at the test centre).

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Part A:

Baseline investigations of bats at Wind Turbine Test Centre Østerild

Morten Elmeros[1], Julie Dahl Møller[2] & Hans Jørgen Baagøe[3]

[1] Aarhus University, Department of Bioscience
[2] JDM Consult
[3] Zoological Museum, National History Museum of Denmark,
Copenhagen University

Stensig Lake in Østerild Plantation where high feeding activity of bats were recorded. Photo: Morten Elmeros.

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Introduction

Mortalities of bats at wind turbines and their effects on the conservation and population status of bats have received much attention in other European and North American countries (e.g. Ahlén 2002, Hötker 2006, Ahlén et al. 2007, Kunz et al. 2007, Rodrigues et al. 2008). Bats are killed by physical trauma as the rotating turbine wings collide with the bat or by barotrauma caused by rapid changes in air pressure near a passing turbine blade (Baerwald et al. 2008, Grodsky et al. 2011, Rollins et al. 2012).

Bat mortality rates at wind turbines are affected by e.g. geographic location, turbine height and wind speed (Hötker 2006, Barclay et al. 2007, Arnett et al. 2008, Dulac 2008, Horn et al. 2008). The highest bat mortalities occur at wind turbines located in or near core habitats as forest and wetlands, and at inland and coastal migration routes (Ahlén 2002, 2010, Kunz et al. 2007, Dulac 2008, Rydell et al. 2011).

The temporal variation in mortalities is considerable in frequency and timing between years, but bat activity around the wind turbines and mortalities usually peaks in late summer and early autumn (e.g. Dulac 2008). The mortality rate increases with increasing turbine height and rotor size, especially at wind turbines in forests (Hötker 2006, Barclay et al. 2007). Most mortalities area recorded at low wind speeds (Baerwald et al. 2009, Arnett et al. 2011).

Bats are relatively long-living species with low reproductive rates. Most females having only one young per year, and many adult females may not breed every year (Kunz & Fenton 2003). These life-history traits render the status of bat populations very susceptible to increased mortalities. Population sizes of bats are poorly known and difficult to monitor. Population models suggest that minor increases in annual mortality rates can result in population declines (Hötker et al. 2006, Rydell et al. 2011).

In Europe, 23 bat species have been recovered dead at wind turbines (Rodrigues et al. 2008, Ahlén 2010, Rydell et al. 2010). There are no published studies on bat behaviour and mortalities at wind turbines in Danish landscapes. Attraction to wind turbines and mortalities of the bat species that occur in Denmark have been documented in studies in neighbouring countries (Ahlén 2002, Hötker 2006, Dulac 2008, Rodrigues et al. 2008).

Bat species in Thy

Bat numbers are relatively low in north and western Denmark (Baagøe 2001). However, the pond bats (*Myotis dasycneme*) and the Daubenton's bat (*Myotis daubentonii*) are relatively common in suitable habitats in eastern Thy. A breeding colony of pond bats is located 3 km from the test centre area in Østerild (Baagøe 2007a, 2007b). Other species recorded in the region includes: Nathusius' pipistrelle (*Pipistrellus nathusii*), soprano pipistrelle (*Pipistrellus pygmaeus*), serotine bat (*Eptesicus serotinus*), parti-coloured bat (*Vespertilio murinus*) and brown long-eared bat (*Plecotus auritus*) (Baagøe 2007c, 2007d, 2007e, 2007f, 2007g).

All bat species in Europe are strictly protected as listed on the Habitats Directive Annex IV (European Commission 1992). The pond bat is also listed on Annex II. Overall conservation status of the pond bat was assessed as 'favourable' in the Atlantic biogeographic region in 2007 (Table 1) (Søgaard et al. 2008). A Special Area of Conservation (SAC) H16 'Løgstør Bredning, Vejlerne og Bulbjerg' neighbouring the test centre area is designated to protect pond bat. The pond bat's conservation status within SAC H16 has been assessed as 'unknown' (Miljøcenter Aalborg 2007). The pond bats that occur in the SAC have breeding and resting sites in the vicinity of the area (Naturstyrelsen 2011).

On the national red list for mammals, the pond bat is designated as 'vulnerable' (VU) based on the few hibernation sites (Elmeros et al. 2010). Internationally the pond bat is red listed as 'near threatened' (NT) (Hutson et al. 2008). The pond bat is endemic to Europe and the Danish population is one of the largest known populations. The Danish population of pond bats is designated a 'species of national responsibility' (ansvarsart) (Naturstyrelsen 2011).

Table 1. Bat species recorded in Thy, conservation and conservation status (CS) in the Atlantic biogeographic region in Denmark following the Habitat Directive Article 17 assessment and the national red list assessment (LC, Least concern; VU, Vulnerable).

			Habitat directive		National
English name	**Danish name**	**Latin name**	**Annex**	**CS**	**Red list**
Pond bat	Damflagermus	*Myotis dasycneme*	II & IV	Favourable	VU
Daubenton's bat	Vandflagermus	*Myotis daubentonii*	IV	Favourable	LC
Nathusius' pipistrelle	Troldflagermus	*Pipistrellus nathusii*	IV	Favourable	LC
Soprano pipistrelle	Dværgflagermus	*Pipistrellus pygmaeus*	IV	Unfavourable	LC
Serotine	Sydflagermus	*Eptesicus serotinus*	IV	Favourable	LC
Parti-coloured bat	Skimmelflagermus	*Vespertilio murinus*	IV	Favourable	LC
Brown long-eared bat	Langøret flagermus	*Plecotus auritus*	IV	Favourable	LC

Objectives

The objectives for the baseline study on bats in Østerild Plantation were to determine the occurrence of bat species and the spatial and temporal variation of bats' use of the test centre area prior to construction of the wind turbines. The baseline study shall also determine suitable periods and sites for a reduced monitoring programme, studies of bat behaviour and attempts to record mortalities in the first years of the operational phase of the test centre.

Materials and methods

The baseline survey of bat occurrence and activity levels in the test centre area and suitable habitats in its vicinity was performed using a non-invasive method based on passive detection of the bats' echolocation calls (Ahlén & Baagøe 1999, Battersby 2010, Søgaard & Baagøe 2011). The survey was carried out using state-of-the-art automatic and manual ultrasound bat detectors in July-October 2011.

Detectors and species identification

Automatic bat monitoring was carried out using Pettersson D500X-detectors (Pettersson Electronik AB), which make real-time, full-spectrum recordings of the bats' echolocation calls. Manual monitoring and direct observation of bat behaviour and use of the test centre area was achieved using Pettersson D1000X ultrasound detectors, which store real-time, full-spectrum recordings of the calls, and Pettersson D240X detectors coupled with an Edirol R09HD recorder. All recordings of bat calls on the automatic recorders and portable recorders were stored and archived as uncompressed wav-files.

Recordings of bat calls were analysed using BatSound 4.01 (Pettersson Elektronik AB) to identify species. Species was identified based on the characteristics of their echolocation calls: frequency band, frequency of maximum energy, duration of the calls and intervals between calls. Recordings of bats from the manual monitoring were also analysed by BatSound to verify species identification in the field.

Bats of the *Myotis* genus (e.g. pond bat, Daubenton's bat (*Myotis daubentonii*), Brandt's bat (*Myotis brandtii*) and Natterer's bat (*Myotis nattereri*) which all occur in Jutland) have very similar echolocation calls. Visual observations of the bats and their flight pattern together with the calls are often needed to differentiate *Myotis* species. The pond bat, however, may have unique calls in certain situations. Pond bat calls at all sites were identified, but many *Myotis* calls could not be identified to species level.

Presence/absence of individual bat species was recorded at each monitoring site and bat activity was recorded as numbers of recorded bat calls per night or per hour. For further information of monitoring methods and species identification from their echolocation calls, see Ahlén & Baagøe (1999) and Baagøe & Ahlén (2001).

Monitoring sites and schedule

Bats were monitored for a total of 18 nights from 1 July to 30 October 2011. Five of the seven projected sites for the erection of wind turbines were monitored with automatic detectors for ca. four nights per month (Table 2, Figure 1). Automatic monitoring on ponds and lakes were not started until August. The test centre area and adjacent habitats were monitored from midsummer to late autumn to record temporal variations in occurrence of bats in the project area.

Table 2. Nights per month when automatic recordings of bat activity were collected at locations near future wind turbine sites in the test centre area and at potentially important feeding sites at lakes and ponds inside the test centre area and in the vicinity in Østerild Plantation in summer and autumn 2011.

Location	July	August	September	October
Site 1	4	4	4	4
Site 3	4	4	4	4
Site 5	4	4	4	4
Site 6	4	4	4	4
Site 7	4	4	4	4
Klastrup Pond	-	2	4	3
Stensig Lake	-	2	4	4
Klitvejen pond	-	-	4	4
Abildhave Pond	-	2	4	4
Tovsig Lake	-	2	-	-

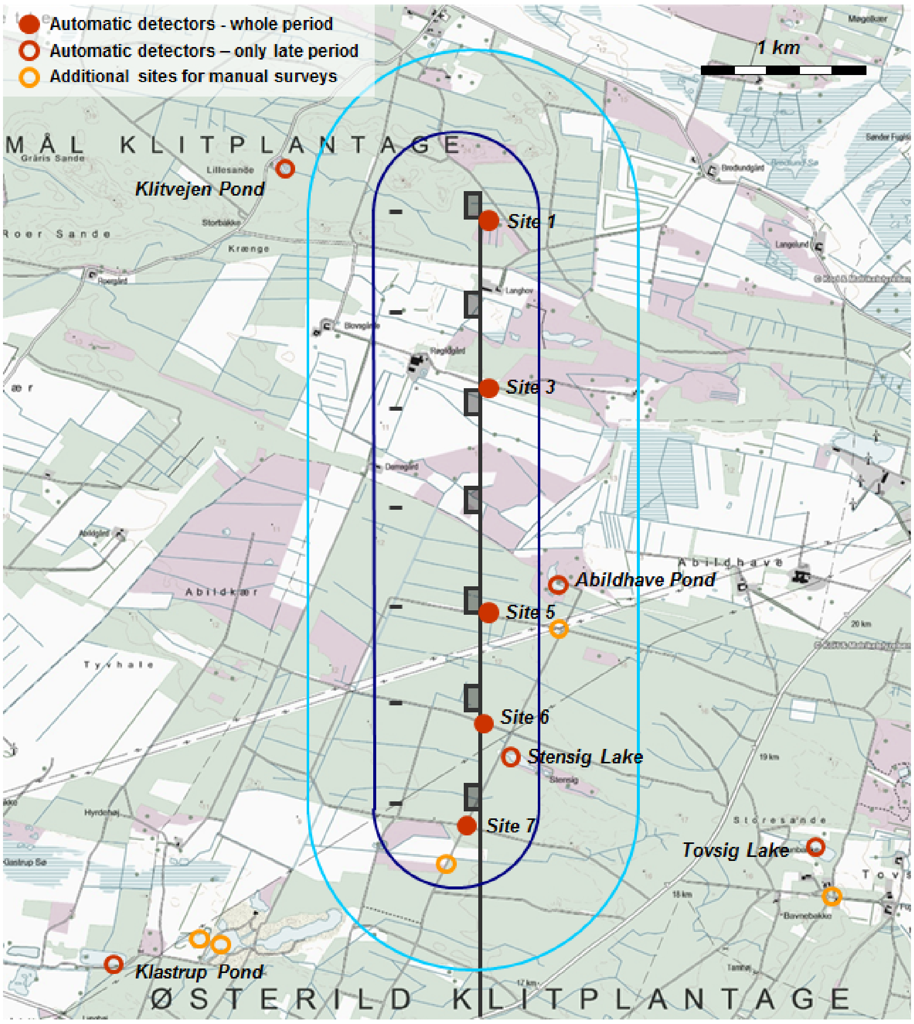


Figure 1. Bat monitoring sites in the national test centre area in Østerild Plantation and in the vicinity. Additional manual registrations were made at roads while commuting between sites. Black lines and boxes indicate roads and construction sites. Blue line: test centre area. Light blue line: wind turbine measuring area (© Kort- og Matrikelstyrelsen).

The detectors were placed in forest edges near roads close to wind turbine sites. The three southern wind turbine sites were monitored as bat activity was assumed to be highest in that part of the plantation, because 1) the forest and landscape structure is most suitable here for bats, 2) of the proximity to the known breeding colony for pond bats and other potential breeding and resting sites for bats, and 3) the two southernmost wind turbines here will be situated in forest. Hence, the highest collisions rates are expected at these southernmost turbines sites.

Bat activity at ponds and lakes in the test centre area and the vicinity was also monitored to determine which species occur in eastern Thy. The survey at sites outside the test centre area also serves as reference for later assessments of potential effects of the test centre facility during the operational phase.

Manual monitoring and direct observations of bat behaviour started on the 1-2 and 2-3 July to screen potential survey sites throughout the whole study area. Manual monitoring was continued on selected nights parallel to the monitoring with automatic detectors.

The monitoring was preferentially undertaken on nights with relatively high temperatures, low wind speed and no precipitation. Local weather forecasts and meteorological data were collected from www.dmi.dk.

Limitations

Bats are active from early spring to late autumn (Baagøe & Degn 2007). It was not possible to obtain a baseline survey of bat occurrence and activity levels throughout an entire season before forest clearing and road development commenced. However, the forest clearing during 2011 is not assumed to have affected the results of the bat survey in any major way.

Noise from insect (grasshoppers and crickets) and vegetation on windy nights impeded the detection efficiency occasionally at some sites.

Quality assurance and data storage

The detection and species identification methods used in this study conform to the methods and high quality criteria that were established in the national monitoring programme for bats (Søgaard & Baagøe 2011). The national programme only aims to describe species distributions at biogeographic levels during the summer at a very low spatial resolution. For the baseline bat survey in Østerild Plantation and the vicinity, the implemented monitoring period was longer and the temporal and spatial intensity was much higher in order to record bats’ use of the test centre area during a longer part of their active period.

Species identification of recordings from selected sites and occurrence of pond bats at all sites was determined independently by two observers.

All recordings are stored electronically as uncompressed audio files (wav-format) at Aarhus University, Department of Bioscience.

Results

Occurrence and dispersion of species

Overall, seven species of bats were detected in the test centre area and its vicinity: pond bat, Daubenton's bat, Nathusius' pipistrelle, soprano pipistrelle, serotine bat, parti-coloured bat and brown long-eared bat.

Pond bat and Daubenton's bat were recorded at all wind turbine sites in the test centre area and at all surveyed ponds and lakes (see Appendix 1). Both species were recorded in the project area from early July until late October.

Nathusius' pipistrelle was recorded at all wind turbine sites in the test centre area and at all ponds and lakes (see Appendix 1). The species is rare in north-western Jutland (Baagøe 2007c), but occurred throughout the project area from early July until late October. A breeding colony of Nathusius' pipistrelle was incidentally found in a building near Tovsig ca. 2 km from the test centre area. This is the first Nathusius' pipistrelle breeding colony ever recorded in Thy (Baagøe 2007c). Later in the summer social calls from male Nathusius' pipistrelle were recorded around the building and at Tovsig Lake.

Serotine bat was recorded regularly but in low numbers throughout the whole study area from early July until late October (see Appendix 1). The serotine bat is common in most parts of Jutland, but has only recently been recorded sporadically in Thy (Baagøe 2007e).

Soprano pipistrelle and parti-coloured bat were recorded sporadically in late summer and autumn. These species are rare in north-western Jutland (Baagøe 2007d, 2007f).

A brown long-eared bat was recorded during manual monitoring in the forest edge along Gl. Aalborgvej south of the test centre area.

Frequency of occurrence and activity level

Bats were detected on 57-100% of surveyed nights on the individual survey sites (Table 3). Frequency of occurrence of bats (% of nights with bats) and bat activity levels (numbers of bat calls) were generally lower along forest roads near the projected wind turbine sites than at lakes and ponds.

Between the wind turbine sites, the highest frequency of nights with bat passes and activity level were recorded at the southernmost sites (Table 4). The relatively low number of bat passes per night at wind turbine sites (max. 11) suggests that the bats recorded on forest roads were primarily commuting along forest roads between foraging and roost sites. Observations of individual bats on forest roads during manual surveys also suggested commuting flights, i.e. bats were flying with a relatively constant heading, speed and height (app. 5-10 m). However, a few buzzes indicating feeding activity by Nathusius' pipistrelle and an unidentified *Myotis* were recorded along forest roads in the plantation.

Table 3. Frequency of occurrence (% of monitored nights) of bats recorded with automatic detectors at sites in the test centre area and in the vicinity within Østerild Plantation in 2011 (see Figure 1 for locations). '*Myotis*' include identified pond bats and Daubenton's bats and unidentified *Myotis* calls. Mdas: pond bat, Mdau: Daubenton's bat, Pnat: Nathusius' pipistrelle, Ppyg: Soprano pipistrelle, Eser: serotine bat, Vmur: parti-coloured bat. Paur: brown long-eared bat. Unknown bat calls were calls that were too weak or short for identification. *The forest edge along Gl. Aalborgvej was only monitored manually for short periods, which explains why only bat occurrence is reported.

Location	All bats	*Myotis*	*Mdas*	*Mdau*	*Pnat*	*Ppyg*	*Eser*	*Vmur*	*Paur*	Unknown
Site 1	57	29	7	21	14	0	7	7	0	0
Site 3	79	50	36	21	21	14	14	0	0	7
Site 5	71	43	21	14	50	7	0	0	0	7
Site 6	88	50	38	13	50	0	6	6	0	0
Site 7	80	67	47	27	67	0	0	0	0	7
Klastrup Pond	89	56	44	22	44	0	11	0	0	22
Stensig Lake	100	100	100	88	88	0	0	25	0	13
Klitvejen Pond	67	50	33	50	50	0	17	0	0	17
Abildhave Pond	100	78	78	44	56	0	0	0	0	11
Tovsig Lake	100	100	100	100	100	0	100	50	0	100
Gl. Aalborgvej*	-	-	-	-	-	-	-	-	x	X

Table 4. Mean (and maximum) numbers of bat calls per night recorded with automatic detectors at sites in the test centre area and at suitable sites in the vicinity within Østerild Plantation during summer and autumn 2011. See Figure 1 for locations and Table 3 for species abbreviations.

Location	*Myotis*	*Pnat*	*Ppyg*	*Eser*	*Vmur*	Unidentified
Site 1	0.3 (1)	0.1 (1)	- (0)	0.1 (1)	0.1 (1)	- (0)
Site 3	0.9 (4)	0.3 (2)	0.1 (1)	0.1 (1)	- (0)	0.1 (1)
Site 5	1.1 (5)	0.6 (2)	0.1 (1)	- (0)	- (0)	0.1 (1)
Site 6	1.4 (6)	0.9 (5)	- (0)	0.1 (1)	0.1 (1)	- (0)
Site 7	3.0 (10)	1.2 (5)	- (0)	- (0)	- (0)	0.1 (1)
Klastrup Pond	13.1 (58)	1.1 (4)	- (0)	0.4 (4)	- (0)	0.2 (1)
Stensig Lake	90.9 (353)	5.0 (14)	- (0)	- (0)	0.3 (1)	0.4 (3)
Klitvejen Pond	8.2 (26)	0.8 (3)	- (0)	0.8 (5)	- (0)	0.2 (1)
Abildhave Pond	91.4 (449)	5.6 (13)	- (0)	- (0)	- (0)	0.1 (1)
Tovsig Lake	67.5 (103)	7.0 (8)	- (0)	5.5 (6)	0.5 (1)	1.0 (1)

The highest numbers of bat calls (especially of *Myotis* bats) were recorded at ponds and lakes in and around the test centre area. The highest bat activity levels were recorded at Stensig Pond inside the test centre area between the two southernmost sites and at Abildhave Pond east of turbine site no. 5.

Bat activity is highest in the first hours after sunset when bats emerge from their roosts and visit the important feeding sites. To compare spatial and temporal variations at survey sites with a more standardized data set, the occurrence of species and number of bat calls for four hours after sunset was calculated.

The frequency of occurrence and activity levels in the first four hours after sunset showed similar trends to the overall results (Table 5 and 6). During September and October, relatively high levels of feeding activity by *Myotis* bats were also recorded later than 4 hours after sunset.

Table 5. Frequency of occurrence (% of monitored nights) of bats recorded during the first 4 hours after sunset recorded with automatic detectors at sites in the test centre area and in the vicinity in Østerild Plantation during summer and autumn 2011. See Figure 1 for locations and Table 3 for species abbreviations.

Location	**All bats**	***Myotis***	***Mdas***	***Mdau***	***Pnat***	***Ppyg***	***Eser***	***Vmur***	**Unknown**
Site 1	57	14	0	14	14	0	0	7	0
Site 3	79	43	36	21	14	14	0	0	7
Site 5	71	21	7	14	21	0	0	0	0
Site 6	88	38	25	6	38	0	6	6	0
Site 7	80	60	47	20	60	0	0	0	7
Klastrup Pond	89	44	33	22	44	0	11	0	22
Stensig Lake	100	100	100	88	88	0	0	13	13
Klitvejen Pond	67	33	33	17	33	0	17	0	17
Abildhave Pond	100	56	56	33	56	0	0	0	11
Tovsig Lake	100	100	100	100	100	0	100	50	0

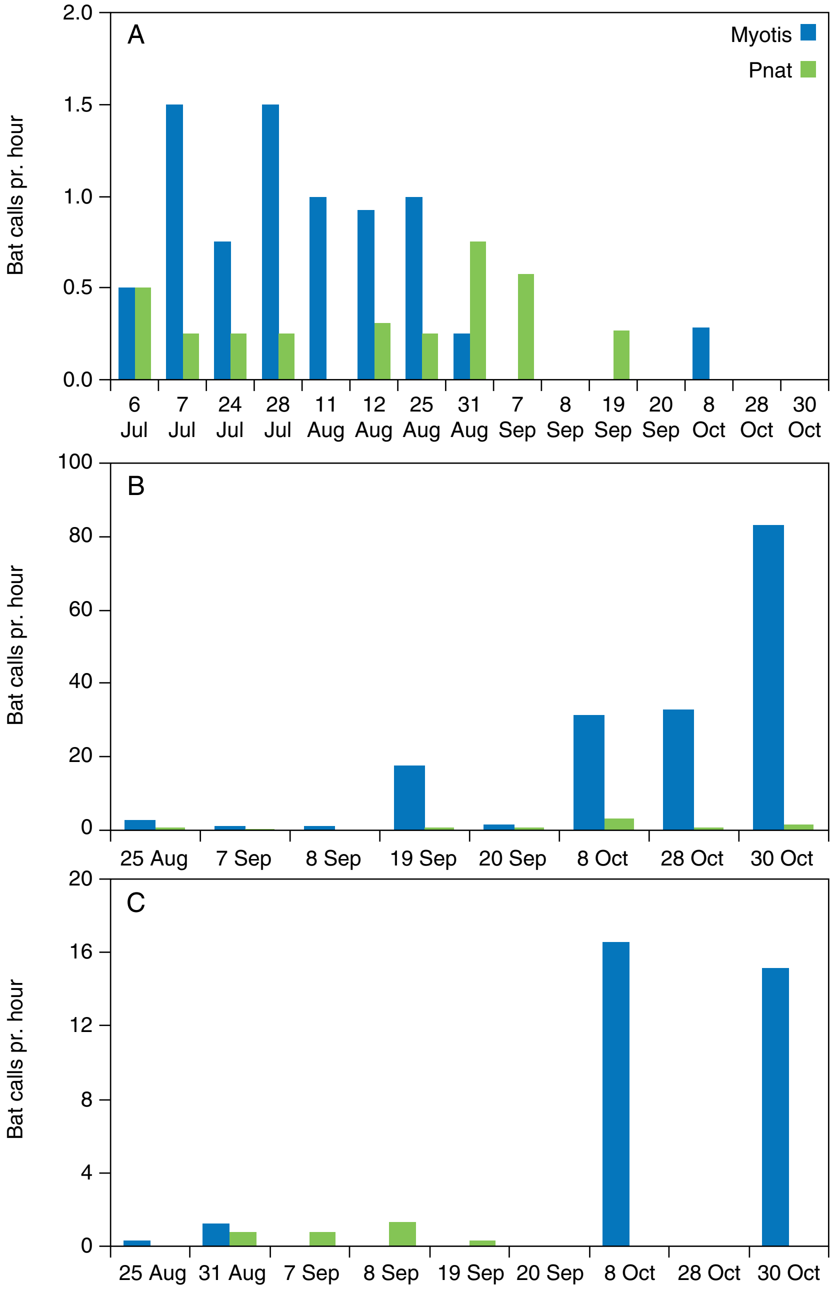
Table 6. Mean (and maximum) number of bat calls per hour per night during the first 4 hours after sunset recorded with automatic detectors at sites in the test centre area and at suitable sites in the vicinity in Østerild Plantation during summer and autumn 2011. See Figure 1 for locations and Table 3 for species abbreviations.

Location	*Myotis*	*Pnat*	*Ppyg*	*Eser*	*Vmur*	Unidentified
Site 1	0.04 (0.25)	0.04 (0.25)	- (0)	- (0)	0.02 (0.25)	- (0)
Site 3	0.18 (0.75)	0.05 (0.50)	0.04 (0.31)	- (0)	- (0)	0.02 (0.25)
Site 5	0.06 (0.75)	0.10 (0.50)	- (0)	- (0)	- (0)	- (0)
Site 6	0.13 (0.75)	0.15 (0.75)	- (0)	0.02 (0.31)	0.02 (0.25)	- (0)
Site 7	0.51 (1.50)	0.23 (0.75)	- (0)	- (0)	- (0)	0.02 (0.25)
Klastrup Pond	3.70 (16.57)	0.35 (1.33)	- (0)	0.11 (1.00)	- (0)	0.07 (0.33)
Stensig Lake	21.50 (83.25)	1.09 (3.14)	- (0)	- (0)	0.03 (0.25)	0.10 (0.80)
Klitvejen Pond	0.29 (1.50)	0.21 (1.00)	- (0)	0.17 (1.00)	- (0)	0.06 (0.33)
Abildhave Pond	15.46 (67.50)	1.26 (2.75)	- (0)	- (0)	- (0)	0.04 (0.36)
Tovsig Lake	15.96 (23.25)	0.67 (1.00)	- (0)	1.33 (1.67)	0.17 (0.33)	- (0)

Many recordings of *Myotis* bats including pond bats and Daubenton's bats at lakes and ponds included feeding buzzes, several recordings included more than one bat, and several *Myotis* bats were observed feeding simultaneously at ponds and lakes. It is not possible to estimate numbers of bats based on the number of bat calls. However, high bat activity levels will indicate the importance of a site, whether more bats is foraging at a site or a few individuals area are foraging at the site for longer periods. Feeding Nathusius' pipistrelle and serotine bats were also recorded at ponds and lakes.

The activity levels varied at individual sites on successive nights, but overall, activity levels of *Myotis* bats (including both pond bats and Daubenton's bats) recorded at ponds and lakes increased during the course of the autumn (Figure 2).

Figure 2. Examples of temporal variation in bat activity (calls per hour) during the first 4 hours after sunset recorded with automatic detectors. *Myotis* species includes pond bats and Daunbenton's bats. Pnat is Nathusius' pipistrelle A: Forest roads near Site no. 7, B: Stensig pond, C: Klastrup Pond. Note the different scale of the y-axes.



Discussion

Occurrence of species

The baseline survey demonstrated that several bat species occur in the test centre area and the vicinity. Three species, the pond bat, Daubenton's bat and Nathusius' pipistrelle, were recorded regularly throughout the entire monitoring period throughout the test centre area and other survey sites. These three species probably also occur in the area in spring and early summer.

Serotine bat, soprano pipistrelle and parti-coloured bat were also recorded the test centre area, while brown long-eared bat was only detected in the plantation outside the test centre area. Previously, the serotine bat has only been recorded sporadically in Thy (Baagøe 2007e). The regular detection of serotine bats suggest that the species is roosting in eastern Thy. As the serotine bat is more associated with open mosaic landscapes, the present monitoring scheme might have underestimated the species' use of habitats in the survey area, as the survey sites were not located optimally to monitor this species.

The brown long-eared bat was only recorded along the forest edge along Gl. Aalborgvej east of the test centre area. Brown long-eared bat is typically associated with deciduous forest and small scale mosaic landscapes (Baagøe 2007g). It is foraging by gleaning with a very weak echolocation call that can only be detected at very close range (<10m). Thus, most parts of the project area are not optimal habitat for brown long-eared bat, but the detectability the species is relative low.

Dispersing and migrating bats are found outside of breeding areas during late summer and autumn. The recorded soprano pipistrelle and parti-coloured bat were probably migrating individuals. The parti-coloured bat may disperse over long distances (>1000km) (Hutterer et al. 2005). The soprano pipistrelle has been recorded in Thy in more suitable habitats during the breeding season in July (Baagøe 2007d). Breeding colonies of soprano pipistrelles are often found close to deciduous or mixed forest, parks and gardens, habitats which are rare in the test centre area. The soprano pipistrelle is relatively sedentary in most of its range, but migratory behaviour has been recorded (Hutterer et al. 2005).

Dispersion and habitat use

Bats were primarily commuting along forest roads near the projected wind turbine sites in the test centre area. The bats made extensive use of wetlands and adjacent forest clearings in the test centre area and the vicinity as feeding habitats. High foraging activity by bats at a site indicates high biomass of favoured insect species of the different bat species. Key foraging habitat may comprise less than 0.1% of a home range (Dietz et al. 2006, Stahlschmidt et al. 2012).

Pond bats have large home ranges. They may hunt more than 15 km from their roost sites and cover larger distances during nocturnal foraging bouts (Limpens et al. 2000). For Daubenton's bats, a mean distance of 2.3 km (range: 0.6-6.3 km) between roosting and foraging site has been recorded for females during the breeding season (Dietz et al. 2006). Maximum distances between roost sites and feeding sites for individual Nathusius' pipistrelles are 2.4–6.6 km (Flaquer et al. 2009). These commuting distances for Nathusius' pipistrelles are conservative estimates as bats were tracked for relatively short periods (<10 d). Home range sizes for serotine bat breeding colonies varied from at least 24-77 km^2 (Robinson & Stebbings 2009). Average commuting distances per night between feeding areas and roost site was 8 km (max. 41 km) for serotine bats.

No systematic attempts were made to locate breeding or resting sites. The conifer stands which dominate the plantation in the test centre area probably offer few suitable breeding and resting sites for bats, but large deciduous trees and buildings which may house breeding colonies of bats are found south and east of the test centre area. The applied survey method is not suitable to determine whether the recorded pond bats and Nathusius' pipistrelle recorded in the plantation originate from the known breeding colonies in Østerild and Tovsig or from other presently unknown colonies. More intensive radio-telemetry studies are needed to establish the roosting sites and flight patterns for the bats recorded in the test centre area and the vicinity (Dietz et al. 2006, Haarsma & Tuitert 2009). However, the test centre area is well within the normal flight distances during feeding bouts from the two known breeding colonies for both species.

A reduced monitoring programme will describe the potential changes in bat occurrence in Østerild Plantation during the first years in the operational phase of the test centre.

Temporal activity patterns

Bats vary their temporal and spatial foraging activity depending on seasonal variations in insect availability and weather conditions (Erickson & West 2002). The activity level of pond bats and Daubenton's bats increased during late summer and autumn at ponds and lakes in the plantation. The sheltered ponds and lakes may have particular high importance for pond bats and Daubenton's bats when foraging conditions on the Limfjord are less optimal, e.g. during periods when insects are not available over the fjord or during windy nights.

The baseline study of bats in Østerild Plantation documents that bat activity vary seasonally and even between successive nights at a site. If bats had only been monitored in the test centre area for one or two nights during midsummer, the importance of the ponds and lakes in the plantation would not have been detected. Systematic surveys throughout the season are required to locate key habitats for the bats and flight patterns to assess impacts of development projects.

Mortalities at wind turbines are highest during late summer and early autumn (Dulac 2008, Rodrigues et al. 2008, Rydell et al. 2010). Studies of bat behaviour will be performed in July and September, when the mortality risk is highest and activity level of bats is highest at sites in the plantation.

Flight altitudes, turbine height and mortality risk

Flight altitude is often used to assess the risk of collisions with wind turbines. Most bat fatalities recorded at wind turbines in Europe represent species that hunt by aerial hawking, e.g. the genera *Pipistrellus*, *Nyctalus*, *Eptesicus* and *Vespertilio* (Rodrigues et al. 2008, Rydell et al. 2010). The fatalities also include species that normally hunts at low altitudes by trawling and gleaning (hunting close to the surface and taking prey on surface) (Rodrigues et al. 2008, Ahlén 2010, Rydell et al. 2010). Bats

Bats change flight patterns and hunting strategies depending on the environs and insect availability, and may adapt their flight altitude and hunt along the turbine tower well above the usual flight altitude. Bat fatalities tend to increase with increasing turbine height (Hötker 2006, Arnett et al. 2008), which suggest that the bats behaviour near the turbines rather than their normal flight altitudes is very important for the mortality risk. Bats appear to be attracted by insects that congregate at the turbine structures (Ahlén 2002, Horn et al. 2008).

Bat potential mortalities will be recorded during the surveys of dead birds at different wind turbines in the first years of the operational phase of the test centre.

Synthesis and application

Six bat species (pond bat, Daubenton's bat, Nathusuis' pipistrelle, soprano pipistrelle, serotine bat, parti-coloured bat) were recorded in the test centre area in Østerild Plantation during the summer and autumn 2011. An additional species, the brown long-eared bat, was recorded in the immediate vicinity of the test centre area.

Bats were present throughout the test centre area during summer and autumn. Pond bat, Daubenton's bat, Nathusuis' pipistrelle and serotine bat probably also occur in the test centre area in spring, while soprano pipistrelle and parti-coloured bat probably occur in the test centre area primarily as dispersing and migrating individuals.

The forest roads were primarily used for commuting between feeding patches and breeding and resting sites. Wetlands inside the test centre area are utilized heavily by bats as foraging habitats, particularly by pond bats and Daubenton's bats during the autumn.

Bat activity varied temporally. There was a marked increase in bat activity at lakes and ponds during late summer and autumn. This stresses the need for long, systematic bat surveys to identify key bat habitats and assess potential effects of construction projects on bats populations.

A reduced bat monitoring programme in the test centre area, studies of bat behaviour near the wind turbines and potential mortalities will be performed during the first years of the operational phase in summer and early autumn. These studies will be focused at the southernmost turbine sites situated in forest and near wetlands and where the highest bat activity was recorded.

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Appendix A.1

Figure App. 1-1. Pond bat recordings in the test centre area in Østerild Plantation and in the vicinity. Foraging pond bats were recorded at all monitored ponds and lakes. Black lines and boxes indicate roads and construction sites. Blue line: test centre area. Light blue line: wind turbine measuring area (© Kort- og Matrikelstyrelsen).

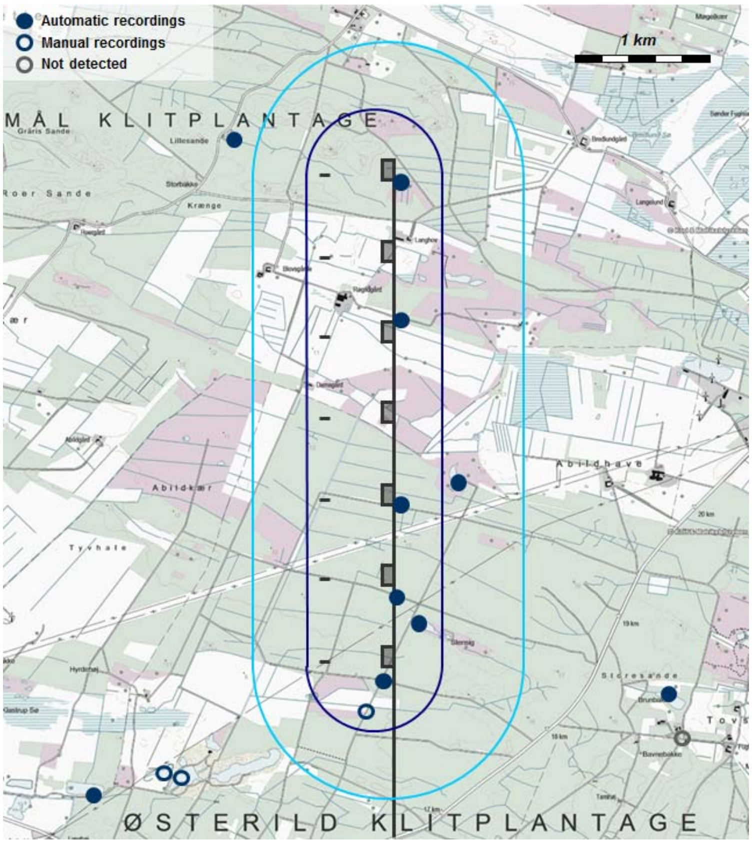


Figure App. 1-2. Daubenton's bat recordings in the test centre area in Østerild Plantation and in the vicinity. Foraging pond bats were recorded at all monitored ponds and lakes. Unidentified *Myotis* bats were also recorded feeding along forest roads at a few occasions. Black lines and boxes indicate roads and construction sites. Blue line: test centre area. Light blue line: wind turbine measuring area (© Kort- og Matrikelstyrelsen).

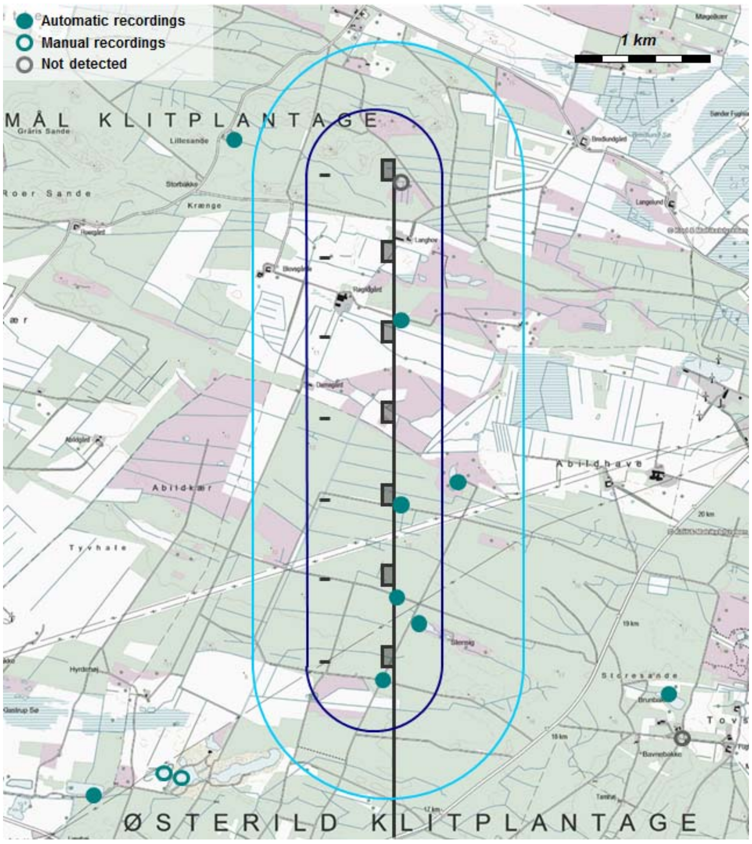


Figure App. 1-3. Nathusius' pipistrelle recordings in the test centre area in Østerild Plantation and in the vicinity. Foraging pond bats were recorded at monitored ponds and lakes and on a few occasions along forest roads. Black lines and boxes indicate roads and construction sites. Blue line: test centre area. Light blue line: wind turbine measuring area (© Kort- og Matrikelstyrelsen).

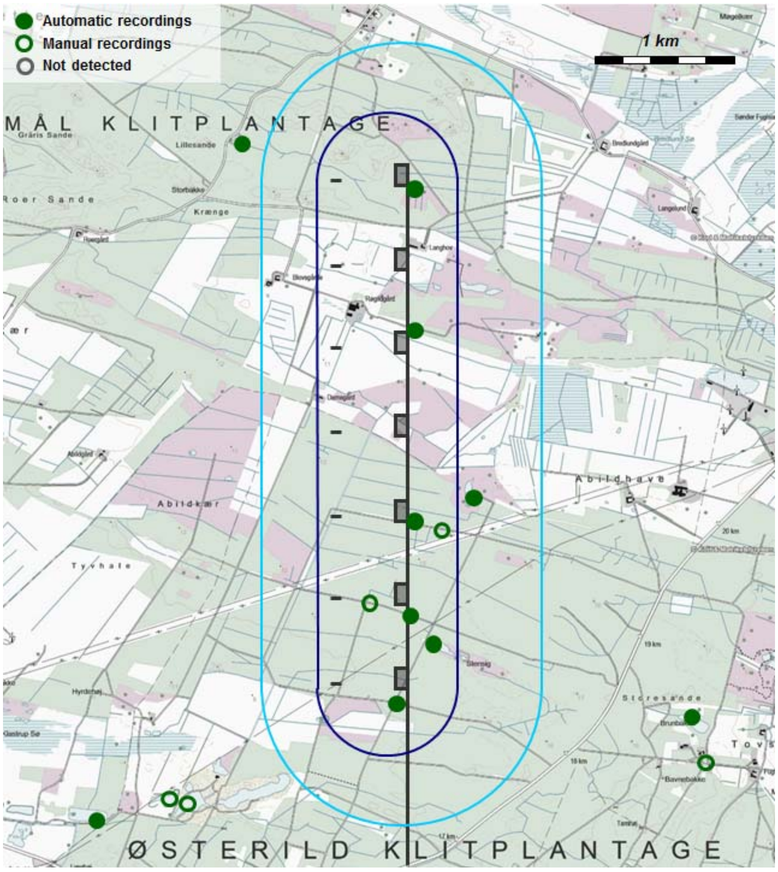


Figure App. 1-4. Serotine bat recordings in the test centre area in Østerild Plantation and in the vicinity. Black lines and boxes indicate roads and construction sites. Blue line: test centre area. Light blue line: wind turbine measuring area (© Kort- og Matrikelstyrelsen).

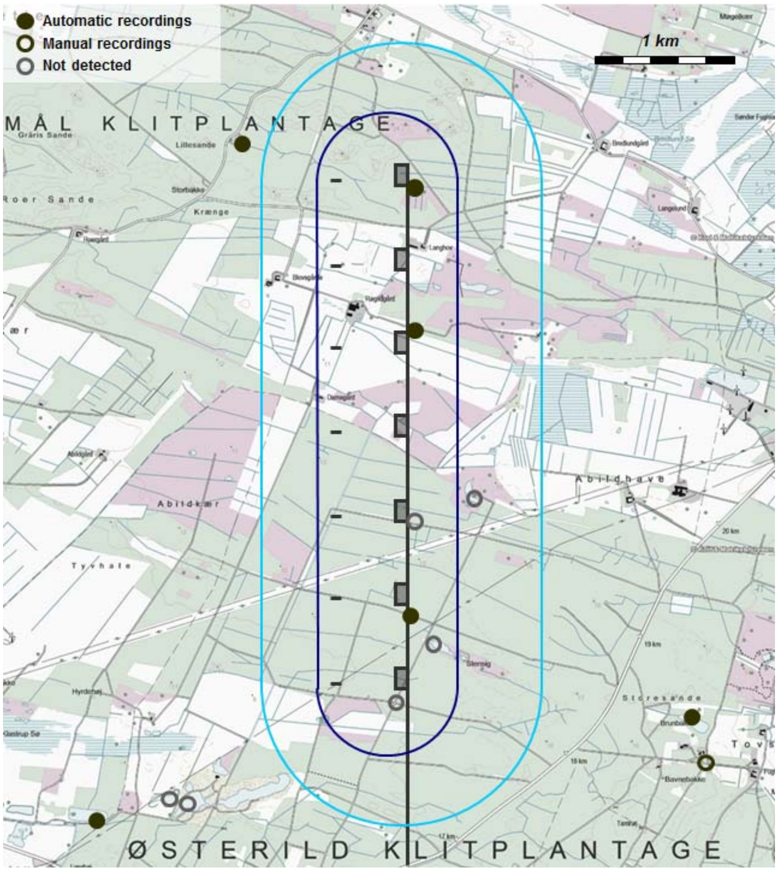


Figure App. 1-5. Soprano pipistrelle recordings in the test centre area in Østerild Plantation and in the vicinity. Black lines and boxes indicate roads and construction sites. Blue line: test centre area. Light blue line: wind turbine measuring area (© Kort- og Matrikelstyrelsen).

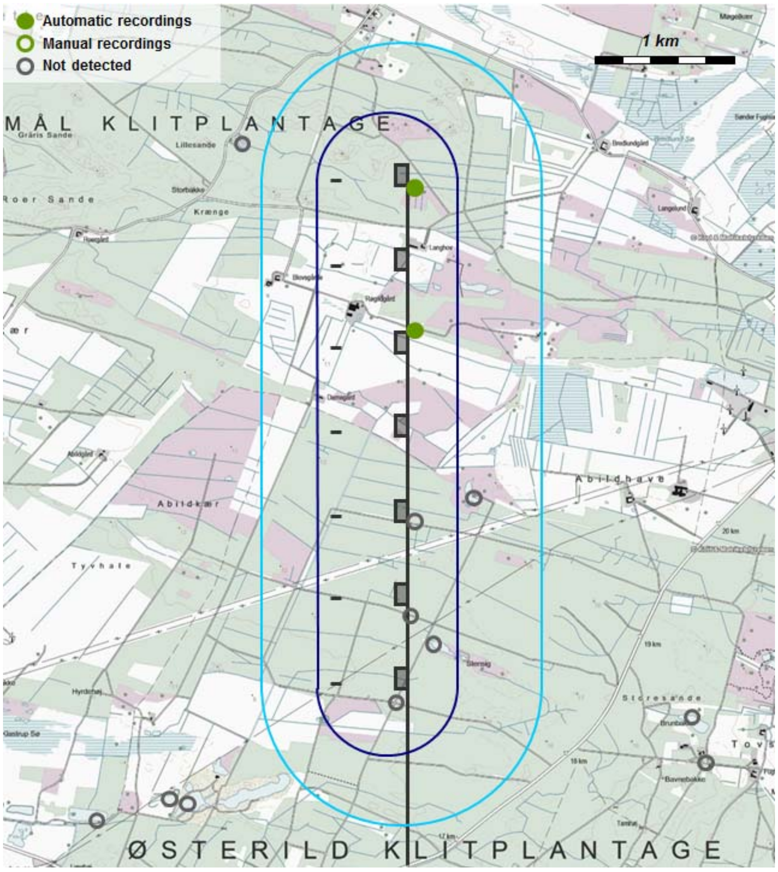
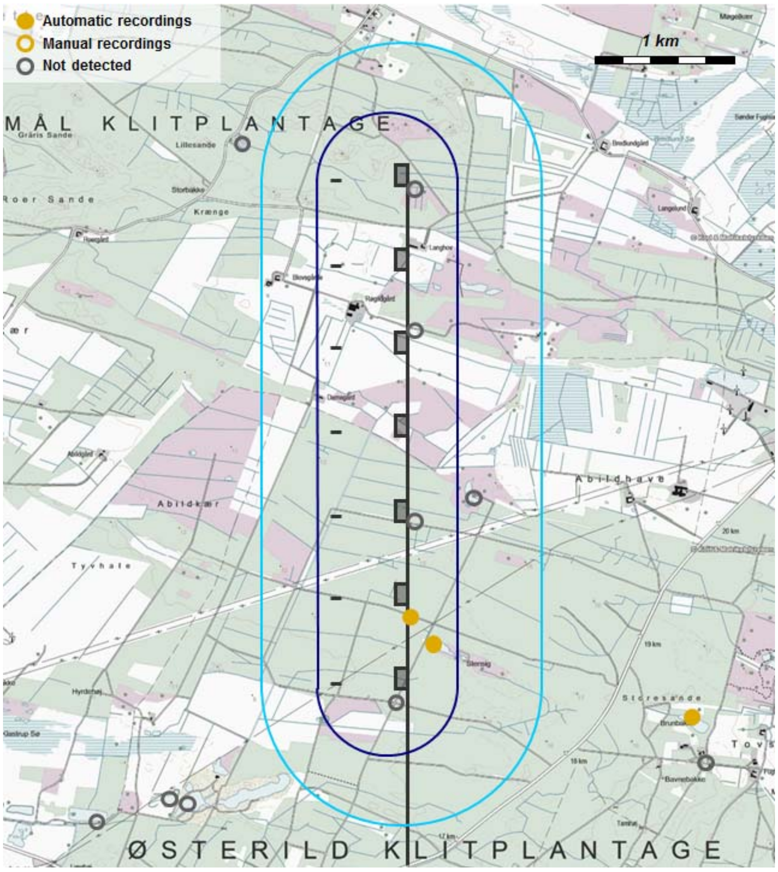


Figure App. 1-6. Parti-coloured bat recordings in the test centre area in Østerild Plantation and in the vicinity. Black lines and boxes indicate roads and construction sites. Blue line: test centre area. Light blue line: wind turbine measuring area (© Kort- og Matrikelstyrelsen).



Appendix A.2

Assessment of projected nature restoration plans

The implementation plan for the national test centre propose measures to compensate the potential effects of the forest clearing and increased mortality risk on the bat populations. The plans calls for creation of forest clearings and increase the proportion of deciduous trees to improve the habitat quality in Østerild Plantation outside of the test centre area and elsewhere in the region (Anon. 2010).

The overall habitat suitability of forest areas for bats is expected to increase if more diverse deciduous stands replace the monocultures of conifer plantations. New forest clearings with natural vegetation will most likely be beneficial for some bat species. However, new forest clearings are not expected to affect the population status of pond bats and Daubenton's bats significantly, as these species primarily forage over lakes and ponds. Furthermore, improved feeding habitats will not improve the status for local bat populations if they are limited by other factors, e.g. the availability of suitable roosting sites.

Modifications to woodland resulting from wind turbine construction, e.g. creation of forest clearings in which turbines are installed and forest edges along access roads, will also increase the heterogeneity of the forest and create improved foraging sites for bats. These forest edges and clearings may function as habitat features guiding bats to the wind turbine sites. Along with wetlands in the test centre area this may result in increased bat activity near the wind turbines. Thus, these modifications of the plantation may result in increased mortalities as bat activity is concentrated near the wind turbine sites.

Whether the projected compensatory measures can compensate for the potentially increased mortality rates in Østerild is not known. To assess the overall effects of the implementation plan, empirical data is needed on the efficiency of the suggested compensatory measures to protect the status of local bat populations.

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Part B:

Baseline investigations of birds at Wind Turbine Test Centre Østerild

Ole Roland Therkildsen[1], Johnny Kahlert[1], Geoffrey Brian Groom[1], Jørgen Peter Kjelsen[2], Henrik Haaning Nielsen[2], Rasmus Due Nielsen[1] & Mark Desholm[1]

[1] Aarhus University, Department of Bioscience
[2] ornit.dk

Field work at Østerild using radar and range finder for the bird studies. Photo: Helge Røjle, DR.

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Introduction

In June 2010, the Danish Parliament passed a bill that regulates the establishment of a national test centre for wind turbines near Østerild in Thy, Denmark. This legislation requires that an environmental monitoring programme should be implemented.

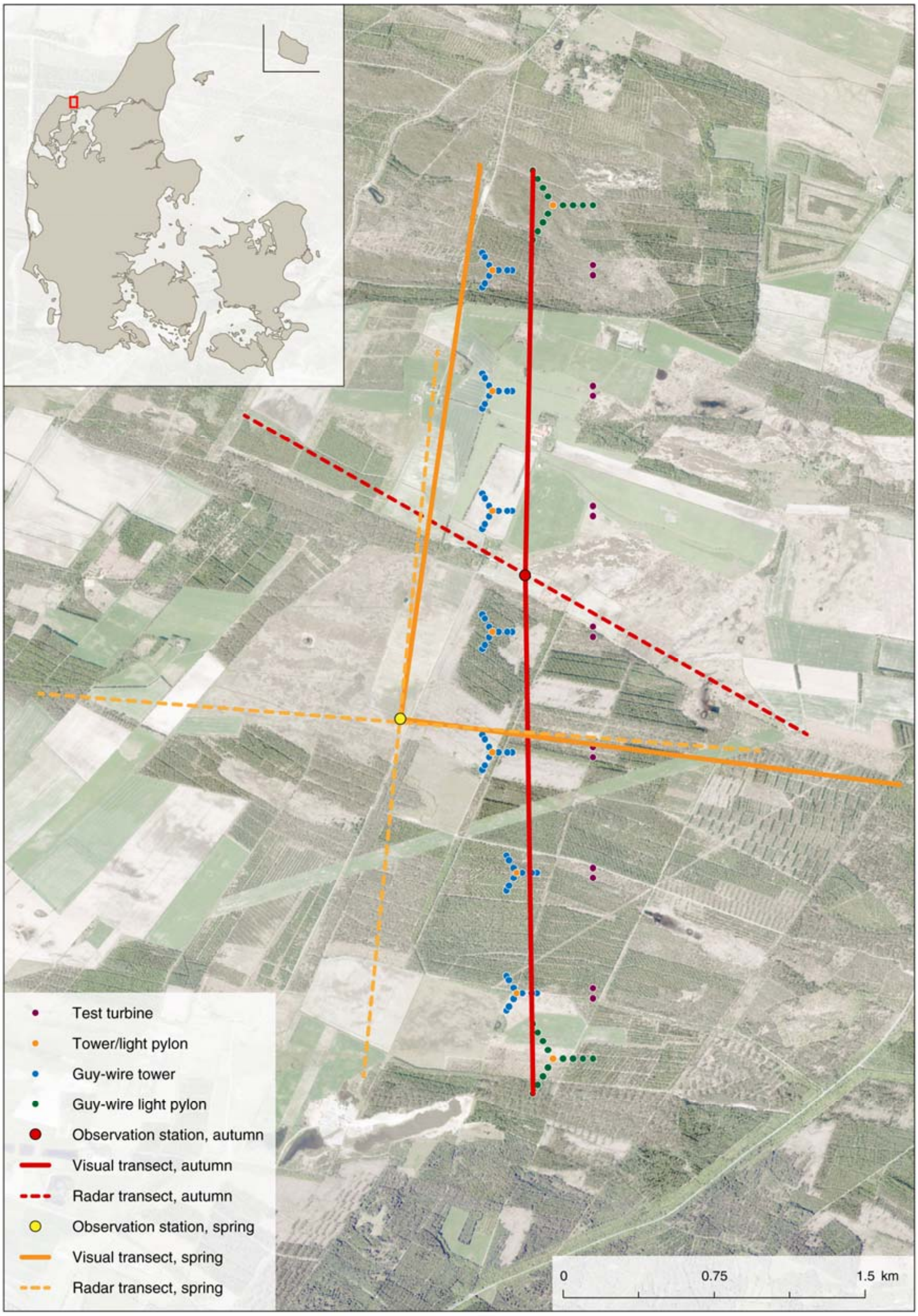
When fully developed, the test centre will comprise a total of seven test sites for wind turbines of up to a maximum height of 250 m. Each test site will consist of a single wind turbine, each with a tower for measuring equipment (up to 150 m in height) located immediately to the west of each turbine. The Test Centre will also require the construction of lit towers supporting meteorological equipment at heights up to 250 m secured with guy-wires. These masts are also expected to be used for aviation safety lighting (see info box and EIA report).

The Department of Bioscience, 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).

Here we present 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.

In addition to the data collected by the Department of Bioscience, Aarhus University, data collected by Grontmij A/S during a preliminary study in spring 2011, was made available for the baseline analysis. It should be noted that Department of Bioscience, Aarhus University, was not part of the planning of the preliminary study and, hence, there is not full compliance between the study design of the two projects. However, the two datasets combined provide a basis for the preliminary assessment of the potential effects on the bird species occurring in the study area.

Methods



Wind Turbine Test Centre Østerild

Figure 1. Wind Turbine Test Centre Østerild with wind turbines, associated structures, observation stations, visual transects and vertical radar transect used for the data collection April-May 2011 and September-November 2011.

The test centre is located in the Østerild Plantation in Northwest Jutland, Denmark, and comprises seven pairs of north-south orientated platforms on which turbines can be erected (Fig. 1). The average distance between platform pairs is 600 m. A maximum of seven turbines will be in operation at the same time. At each pair of platforms, it is proposed that as one turbine is dismantled, a new one can be deployed. 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 100 m.

A tower supporting measuring equipment for the turbines will be associated with each turbine platform pair 500 m west of each platform (Fig. 1). Hereafter, we refer to these towers as “measurement towers”. Towers are triangular lattice masts, 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 are 38 mm in diameter. The measurement towers are each secured with three sets of guy-wires. Each set is expected to comprise 2-4 individual guy-wires, dependent on the height of the tower. The cross sectional diameter of the guy-wires is 25 mm and they will be anchored at different heights.

Furthermore, masts supporting meteorological measuring equipment (hereafter “lit met masts” will be placed 360 m NW of the northernmost and 360 m SW of the southernmost turbine platform, reaching a height of 250 m. The pipes and guy-wires are the same type as those used for the measurement towers. Each of the three guy-wire sets includes seven individual guy-wires. 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. Presently, no information exists on the lighting of turbines and measurement towers.

Conservation issues

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 by wind turbines
- When birds undertake aerial pursuit of prey.

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. 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 in Blåvand (autumn) and Skagen (spring), which form geographic bottlenecks for avian migration, real migrants are not expected to be concentrated at the test centre to any large extent. In addition, birds of prey, which are more likely to migrate during the middle of the day, may use woods as guidelines.

Because of the lack of topographical features to concentrate avian migration, under normal circumstances, we would not expect high densities of migrating birds to be concentrated in or near the test area. 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.

Since the test centre is not situated on a migration corridor, we assumed that daytime local movements accounts for more passages of birds at rotor height within the area than genuine seasonal migration. In a previous study of a proposed expansion of the wind farm at Klim Fjordholme, we demonstrated that the 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. Therefore, we considered local movements to represent a greater source of potential collisions with wind turbines, although the design of the baseline programme allows for an assessment of the collision risk associated with both types of migration/movement.

The test centre is located near several Special Protection Areas (SPAs), which are sites designated for their particular importance for birds according to Article 4 of the EC Birds Directive. 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.

Focal species

On the basis of a preliminary assessment, the following four focal species, for which SPAs have been designated in the vicinity of the test centre, were included in the ornithological investigations. These four 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 maneuverability
- They are long distance migrants, but 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 Denmark and Great Britain, 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 breeding areas in April.

Pink-footed goose

Figure 2. Pink-footed geese in the study area. Photo: Jørgen Peter Kjeldsen, ornit.dk.

Northwest Jutland, in particular Vejlerne, constitutes an important area for pink-footed geese (Fig. 2), 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 Hanherred, including Vejlerne, constitute an important area for common cranes, which typically occur in the area from March until late November. In 2011, 31-35 pairs were breeding in Thy and Hanherred of which 6 pairs were found in Vejlerne (Kjeldsen & Nielsen 2011, Nyegaard 2012). In 2012, this number had increased to 10 pairs (J.P. Kjeldsen unpubl.). 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.

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. However, no attempt was made to collect data on nightjars during the baseline programme. This will be a priority in the post-construction programme, where data on the occurrence of nightjars, which may potentially be foraging in close proximity to the turbines, will be collected to assess 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

The baseline programme was designed to generate species specific data, whenever this was technically possible. Therefore, to minimize the loss of species specific information, the collection of baseline data was only partly based on comprehensive automated recording processes. Instead, we focused on the collection of high quality and high resolution data at the species level. We used visual transect counts, vertical radar and laser range finder data, which in combination provided the basic information for the ornithological assessment.

The baseline programme used 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 ensures that baseline data will be compatible with post-construction data providing a reference for the final assessment of the potential impacts of the test centre on relevant bird species.

Visual transect counts

Visual counts have the advantage of providing a detailed quantitative species specific description of bird migration during daytime. During autumn and winter, visual counts were carried out from a central observation station, along transects orientated in southerly and northerly directions situated between the turbine platforms and the measurement towers (see Fig. 1). During spring, visual transect counts were undertaken from a location west of the turbines and measurement towers.

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 and other structures.
- To provide a species specific baseline description of the migration intensity and flight direction at the location of the planned structures in the study area as a basis for future post-construction comparisons, in order to determine and describe species-specific avian 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 B for details). Observers used binoculars and telescope.

The species specific autumn and winter 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, visibility, cloud cover, precipitation, time of the day and month were analysed for selected species, using general linear models. Months, which contributed less than 10% of the total avian observations (movements and migration combined), were excluded from the analyses. In order to exclude insignificant factors a stepwise modelling approach was applied in the first step (using software: SAS 9.3, proc GLMSELECT, with entry and retention in the model at $P < 0.15$). In order to further explore the direction, strength and significance of the correlation between numbers and the covariates selected in the first step, a re-modelling was undertaken in the SAS-procedure "proc GENMOD", using a zero-inflated negative binomial error term. Thus, despite the preliminary exclusion of many zero-counts, the irregular occurrence of many species, even during their main period of migration or overwintering, still produced many 15-minute periods without observations of individual 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 considers the numerical response to factors.

Table 1. The number of 15 minute transect counts carried out each month during the baseline programme at the Østerild Turbine test Centre during daytime. Late spring was defined as the period from April 29 until May 26.

	2011					2012	
Transect	**Late spring**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**
East	18						
North I	17						
North II		71	43	28	24	26	33
South		70	43	28	24	25	32
Total	35	141	86	56	48	51	65

Figure 3. The hand-held laser range finder used by a bird observer. Photo: Helge Røjle, DR.

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 (Fig. 3), and therefore data can be collected in all directions in contrast to a vertically operated radar unit that can only covers avian movements in airspace in two dimensions, unless the position of the entire antenna unit is reorientated (e.g. horizontal to vertical mounting). Hence, a laser range finder is a very flexible and efficient device, when species specific data on flight altitudes of the visible migration of birds are required to be collected 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 the low-flying local movements of large birds (e.g. between foraging areas). However, the study area does not represent a daytime migration hot-spot of 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 first preliminary estimation and assessment of the collision risk at turbines and other structures
- 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 a comparison with future post-construction 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) 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 maps of flight paths and to calculate the distance of flight paths and individual points of measurements to the nearest planned structure categorized as turbines, measurement towers, lit met masts, guy-wires to measurement towers and guy-wires to lit met masts.

The species specific data on flight altitude were combined with weather data, and the effects on the flight altitude from wind direction (SW, NW, SE and NE), wind speed, temperature, visibility, cloud cover and precipitation, time of the night, day number and flock size were analysed using general linear models. Only the mean flight altitude of flocks on which repeated measurements had been obtained was used to avoid pseudo-replication.

Flight altitude and flock size were log-transformed to make the skewed distribution of the data more uniform and provide a better fit to the normal distribution. In order to exclude insignificant factors a stepwise modelling approach was applied in the first step (software: SAS 9.3, proc GLMSELECT, with entry and retention in the model at $P < 0.15$). In order to further explore the direction, strength and significance of the correlation between flight altitude and the covariates selected in the first step, a re-modelling was undertaken in the SAS-procedure "proc GLM".

Radar

A marine surveillance radar unit (Furuno FAR 2X27BB, X-band, 25 kW, 8 foot antenna) 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. Radars operated in a horizontal mode have an unsurpassed accuracy on a large spatial scale, as large birds may be tracked up to a distance of 20 km. However, the efficiency of a radar is hampered by landscape elements such as trees, which covered large parts of the study area during most of the baseline study. This combined with the fact that the area occupied by turbines and towers at the test centre is relatively small meant that it was considered most cost-efficient to primarily use a laser range finder to gather and describe bird movements during daytime. By contrast, radar studies focused on nocturnal bird movements and on a small spatial scale around the test centre structures, only using vertically operated radar, which however provided data on flight altitude. Nevertheless, preliminary data set obtained from the spring 2011 study provided useful background descriptions of flight paths from a larger spatial scale obtained by a horizontally scanning radar. It is essential to note that a radar provides no direct species-identification of the birds, unless combined with visual observation (see previous section).

Vertical radar

The aims of the surveys associated with a vertically operated radar unit (Fig. 4) were:

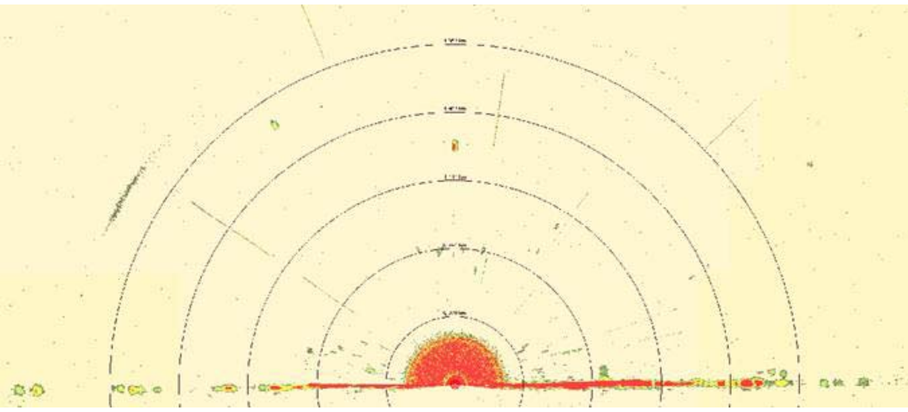
- To obtain measurements of flight altitudes and relative migration/movement intensity primarily during night-time, when other methods are hampered by limited visibility
- Data will serve as a reference for the final assessment of the collision risk of nocturnal migrants.

Figure 4. The radar unit shown operating vertically at the central observation station in the study area. Photo: Jørgen Peter Kjeldsen, ornit.dk

Autumn

The majority of nocturnal data obtained from the vertically operated radar unit was collected during the period from September 1 until November 14, the main autumn period of avian nocturnal migration. Data were collected along a NW-SE-orientated transect (Fig. 1) and the radar range was 1.852 m - the maximum distance tolerated 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 radar (Fig. 5). An object-based image analysis (OBIA) was undertaken of the images on the screen (Fig. 6) and the bird echoes were automatically extracted from screen-dump images by a computer based track recognition procedure (software: Definens, ArcGIS). In this process false echoes and echoes from landscape elements (tree, buildings etc.) were excluded by masking areas with static echoes identified by analysis of 20-30% of the images from each night of data collection. Further quality assurance was undertaken, as the OBIA tended to include small echoes in the pool of potential bird echoes that were below threshold size. A sample of 117 randomly selected echoes was checked manually by an experienced radar ornithologist in order to establish the relationship between the area of echoes and probability of being a bird echo (Fig. 6). Echoes smaller than 295 m^2 (as a relative measure on the screen-dumps) were excluded from the analysis, as these had a probability of less than 90% of being bird echoes (based on logistic regression analysis, see below).

Figure 5. Example of a screen capture of the radar image during vertical avian data collection. Bird migration is depicted as green, yellow and red spots. Large red and yellow aggregations are signals from the ground or false echoes.



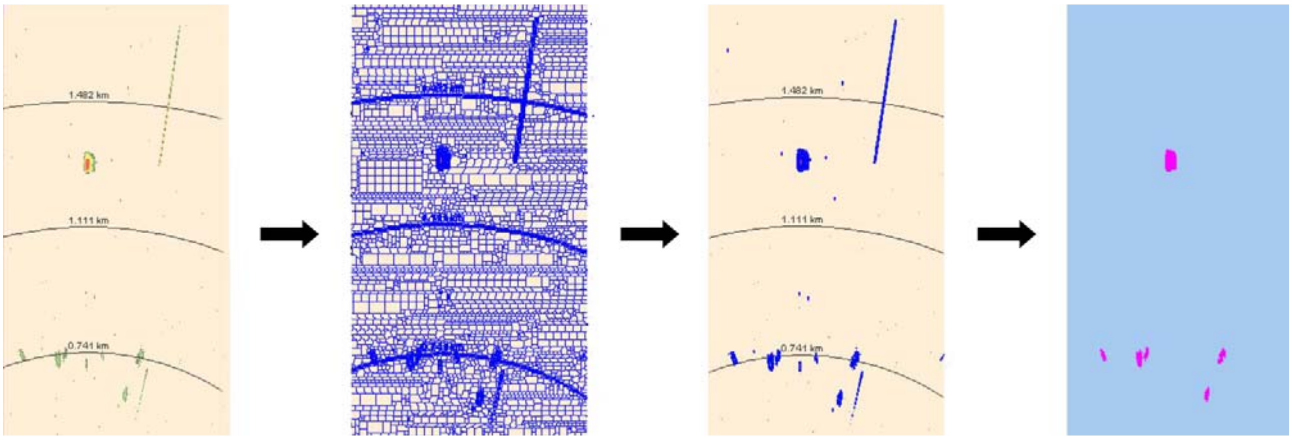
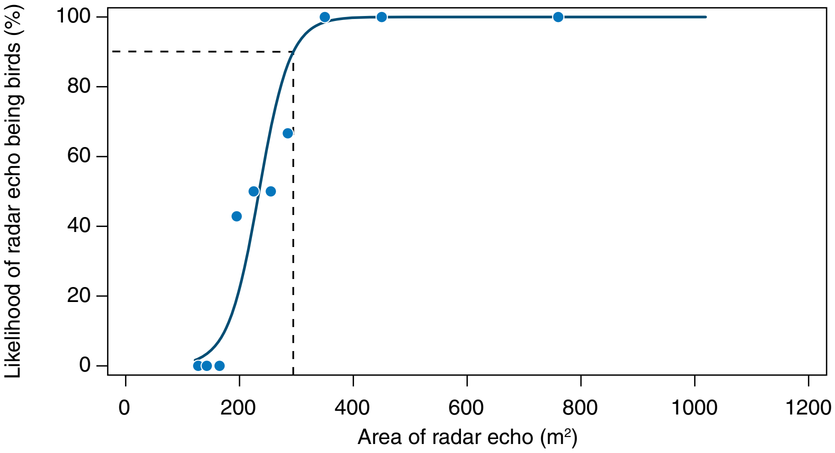


Figure 6. Examples of screen-dumps at different stages of the object-based image analysis (OBIA) showing the extraction of original bird echoes from the radar screen-dumps (extreme left figure) for ultimate extraction as avian objects (extreme right figure).

Figure 7. The probability of a radar echo being a bird as a function of the area of the echo (note that the radar software amplifies an echo to make it visible on the radar screen thereby overestimating the area of the echo).



The area covered by vertically operated radar is a half circle above the ground with the centre at the radar station (Fig. 5). The radar beam was emitted in an angle of 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 static echoes (so-called 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.

Spring

The preliminary study undertaken by Grontmij A/S that initiated the baseline study during spring 2011 used a slightly different approach in the data collection sessions with vertical radar. First, data were collected throughout the 24 hour period. Second, data were collected on two transects (N-S and E-W) (Fig. 1). Third, data were collected manually by a radar operator, who digitized echoes as they appeared on the data screen. Fourth, it was not possible to correct for clutter due to landscape elements.

Data were collected on five dates: April 10 and 29 and May 13, 25 and 26. The majority of the data was collected during daytime. Altitude profiles were calculated, however, due to the limited data collection during nighttime no further analysis was presented.

Horizontal radar

A horizontally operated radar unit was placed less than 500 m west of the row of the measurement towers (Fig. 1). Horizontal radar data (bird tracks) provided detailed temporal and spatial information of bird movements, as well as information on flight direction. Visual verification of bird tracks during daytime was crucial to provide quality data and confirm reflections to species, enabling species specific analyses and assessments. A horizontally operated radar unit therefore requires two persons in constant contact (a radar operator and an observer). Data from horizontal radar were collected during a limited period (preliminary study) on five dates: April 10 and 29 and May 13, 25 and 26, and flight paths were represented on maps.

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 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.

In order to explore the flight patterns at the test centre in further detail, the flight directions observed during the baseline study was 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 as being 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 and peregrine falcon. In addition, it was also applied to raven and wood pigeon, which may also potentially undertake the same flight behaviour.

The results of 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 n_{cros} in Appendix B, 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 B 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, 50-250 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).

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

Other structures

Bird collisions at towers 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, yet they seem to be considerably more dangerous to migrating birds than the tower 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 with little contrast against a background of grey clouds).

Given our great lack of knowledge with respect to bird collisions at towers 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 the towers and lit met masts at the test centre. This meta-analysis confirmed the hypothesis that the number of casualties increased significantly with the height of the tower. By describing this relationship as a mathematical function (linear regression of the logarithm to the number of casualties and tower height), the heights of the Østerild towers 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 associated with great caution and can only be considered as a rough guideline. For example the migration intensity could also affect the number of casualties at tall towers. This factor was not incorporated in the equation, and hence we assume that migration intensities are comparable between the North American towers and Østerild, which may not be the case.

Meteorological data

During the initial study conducted by Grontmij A/S in April-May 2011, no systematic observations were undertaken with respect to cloud cover, visibility and precipitation. During the baseline study period from September 2011 until the end of February 2012, these data were collected at the initiation of each transect count.

Data on wind conditions and temperature are also 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., in press). 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 to other areas. For this reason, it was considered important to model the effects of meteorological variables on flight movements of different focal species.

It was not possible to obtain data from the study area from the entire study period. In order to ensure consistent data sets across the study period, wind data were obtained from a weather station in Hanstholm (courtesy of the Danish Meteorological Institute ca. 18 km NW of the study area; data collected at a height of 22 m above the ground). Temperature data were compiled from a weather station in Silstrup (courtesy of the Danish Meteorological Institute ca. 20 km SE of the study area; data collected at a height of 2 m above the ground).

Quality assurance and data storage

Quality assurance measures were integrated in all stages of the baseline study. 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 and any errors detected were corrected. All analyses, including statistical 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.

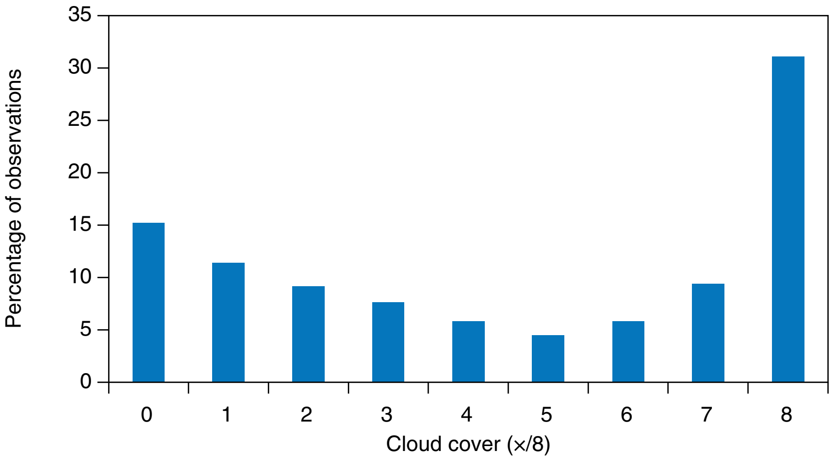
Results

Meteorological observations

Cloud cover

In about 50% of the observation sessions the cloud cover was 5/8 or more, and only around 15% 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. 8).

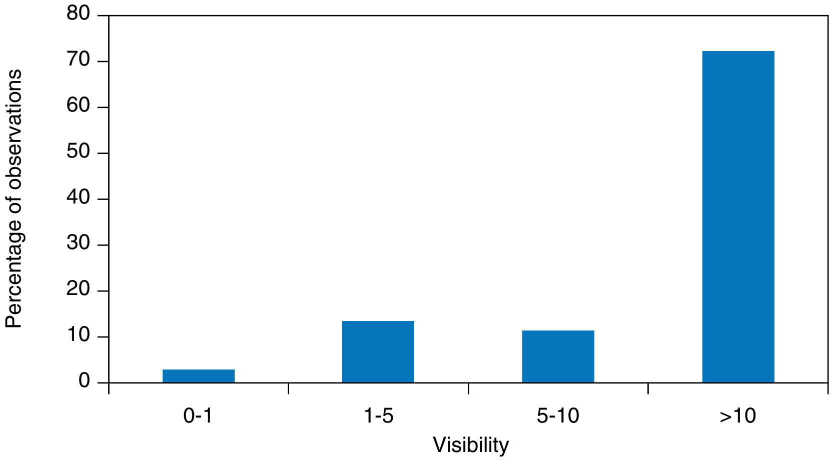
Figure 8. Cloud cover recorded during field work in the study area during the period 2 September 2011 to 26 February 2012.



Visibility

In general, the visibility recorded during field work was good and in more than 80% of the sessions, visibility was more than 5 km (Fig. 9).

Figure 9. Visibility recorded during field work in the study area during the period 2 September 2011 to 26 February 2012.



Precipitation

Almost 95% of all observation sessions were made during periods with no precipitation (Fig. 10).

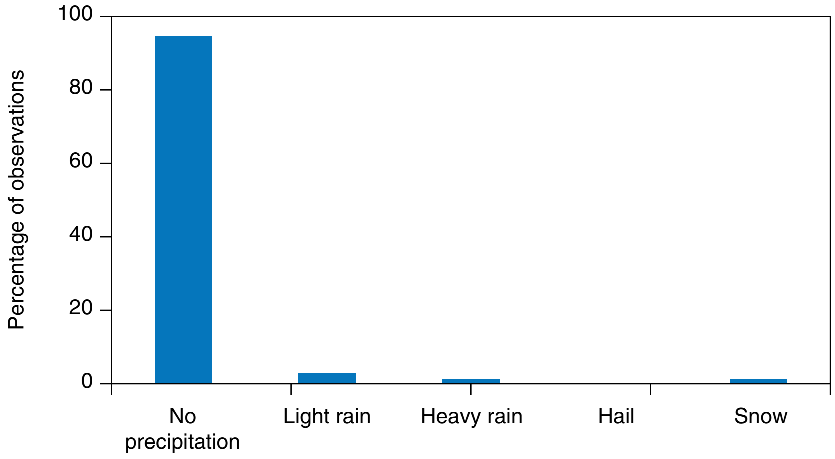


Figure 10. Precipitation recorded during field work in the study area during the period from 2 September 2011 to 26 February 2012.

Overall, observation conditions were favourable, which reflect the fact that observation days were chosen to ensure that sufficient data were collected during the baseline programme. However, it should be noted that weather conditions showed some variation, which means that occasionally observations were made during periods with rain, snow fall and low visibility.

Wind conditions and temperatures

In spring 2011, prevailing winds were from a southerly direction, although there were periods of shorter duration with easterly winds in late April and early May 2011. In autumn 2011, the direction of the wind generally showed great variation with winds from both easterly and northerly directions, although prevailing winds were from a south westerly direction. This was also the case during the winter 2011/12, although a cold spell in early February was caused by winds from an easterly direction (Fig. 11,12).

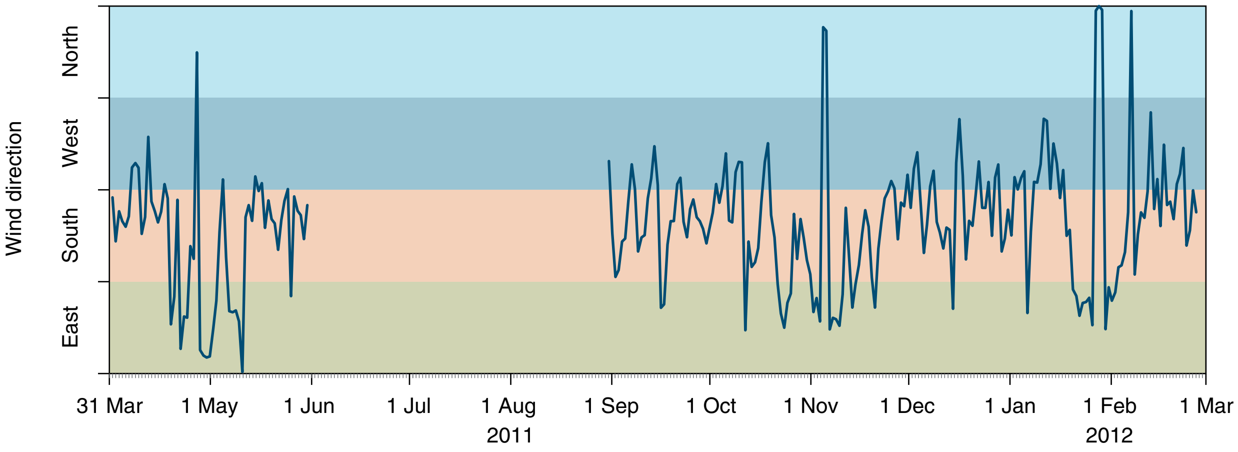


Figure 11. Daily mean wind direction broken into four main directions. Data were compiled at a met mast in Hanstholm during the period April to May 2011 and September to February 2012. Data from the Danish Meteorological Institute.

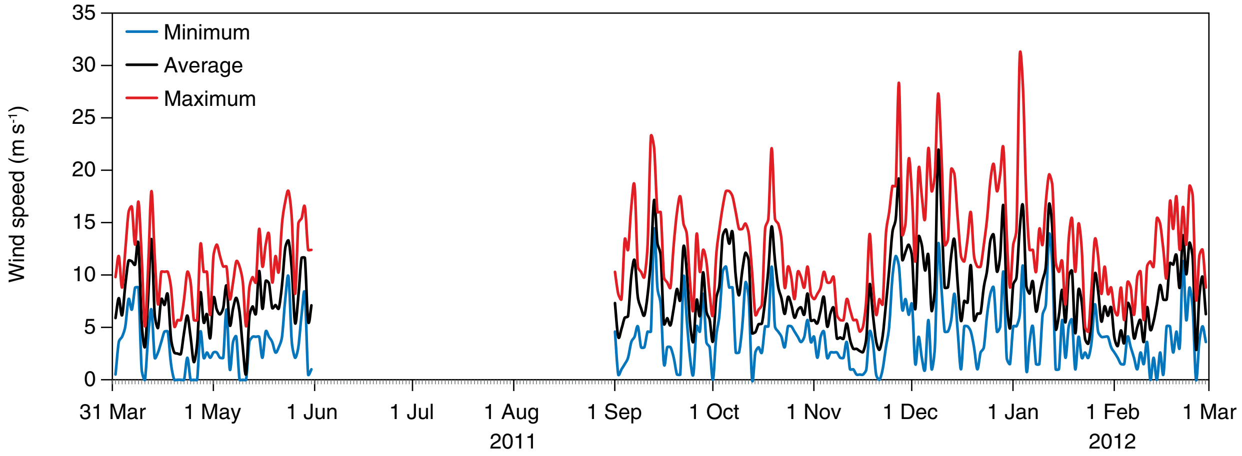


Figure 12. Daily minimum, mean and maximum wind speed based on data compiled at a met mast in Hanstholm during the period April to May 2011 and September to February 2012. Data from the Danish Meteorological Institute.

In spring, mean daily temperature increased from approximately 8 °C in the beginning of April to 11 °C in late May (Fig. 13). In autumn, mean daily temperature decreased from approximately 15 °C in early September to 7 °C in late November. In winter, mean daily temperature was rather stable at around 4 °C, except in early February, when temperatures dropped to -6 °C.

Altogether, spring 2011 was warmer than normal with April being the warmest ever measured in Denmark. Autumn 2011 was on average 1.4°C warmer than normal. Despite a cold spell in February, the winter 2011/2012 was on average 2.0 °C warmer than normal, although winter temperatures were comparable to those measured during the preceding two decades (Danish Meteorological Institute).

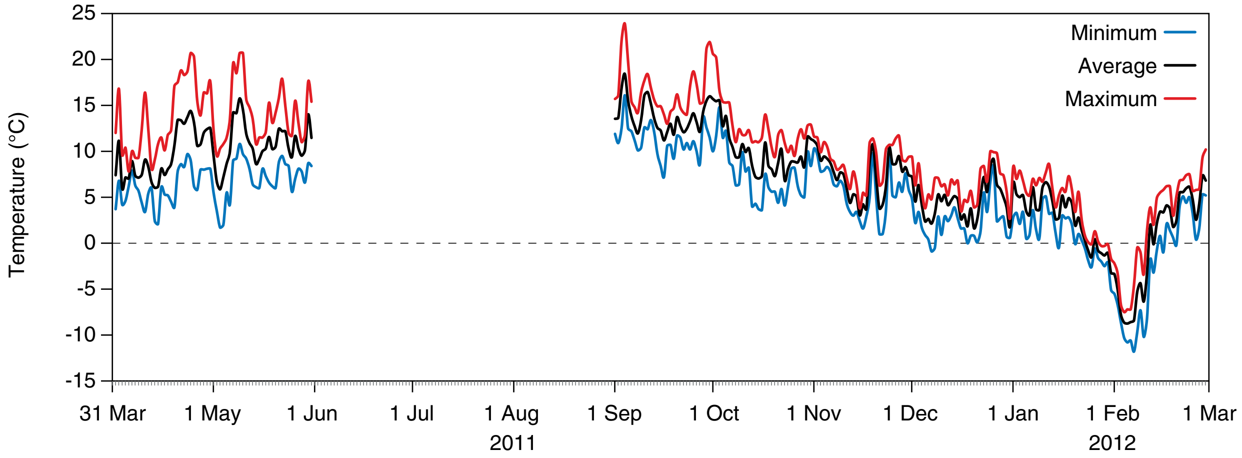


Figure 13. Daily minimum, mean and maximum temperature based on data compiled at a met mast in Silstrup during the period April to May 2011 and September to February 2012. Data from the Danish Meteorological Institute.

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 baseline analysis (see species account below). However, we only provide an overall prediction, which includes all species registered in the study area, for the number of collisions with other structures (measurement towers and lit met masts).

From the outset, several factors are likely to affect the variation in the number of collisions at towers: reduced visibility (fog, darkness), the capability of avoidance, the presence of guy-wires and the tower height which may potentially overlap with strata preferred by migrating birds (e.g. Gauthreaux & Belser 2006, Montevecchi 2006, Longcore et al. 2008). While avoidance, limited visibility, guy-wires and tower height are all likely to be important factors at the test centre, topography is probably not. Thus, the planned deforestation of the area is expected to blur the funnel effect observed along the cultivated strips in the forested landscape during the baseline study (e.g. shown by whooper swans).

In order to provide a crude estimate of the expected number of collisions at the towers, a simple equation was derived from the relationship between tower height and the number of casualties at other study sites (Fig. 14). The heights of the towers at the test centre were inserted in the equation and the expected number of casualties at individual towers was multiplied by the number of towers. This resulted in an annual number of casualties of approximately 750 to 1050 individuals (Tab. 2). It should be noted that the estimate is based on North American studies and therefore the results should be interpreted with great caution, when applied to Danish conditions (i.e. the estimate does not take into account that bird abundance may be very different at Østerild).

A collection of bird casualties from the Øresund Bridge from 2001-2003 suggested that passerines account for a large proportion (78%) of the collisions with man-made structures. Nocturnal migrants (warblers and thrushes) account for the vast majority of these collisions (Nilsson & Green 2002, Nilsson 2003, 2004). However, at Østerild the proportion of passerines is likely to be smaller given that there are relatively large numbers of geese and swans that commute between foraging areas also during periods with dusk and darkness, which is also associated with an elevated risk of collisions.

Figure 14. The annual number of bird casualties as a function of tower height (log scale) at 18 North American study sites (only towers with guy-wires, after Longcore et al. 2010).

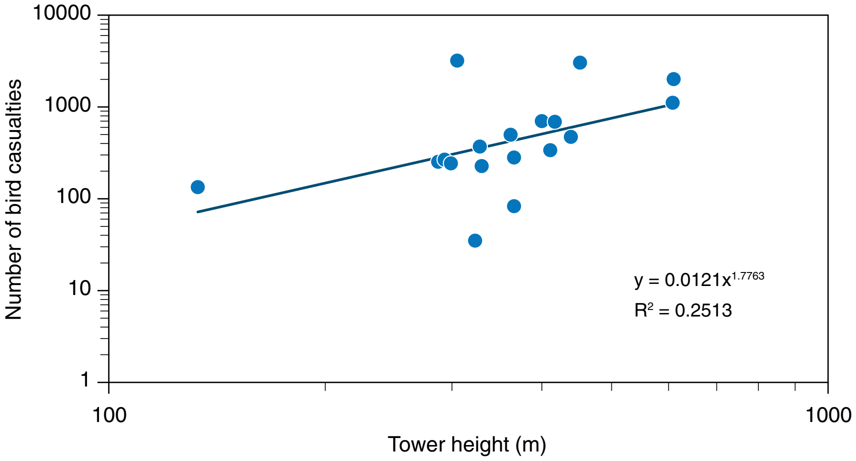


Table 2. Crude estimates of the predicted annual number of bird casualties at towers in the Østerild Test Centre.

Type of tower	Height (m)	Number of structures	Predicted annual number of casualties
Lit met masts	250	2	440
Measurement towers	100-150	7	302-621

Results on selected species

Besides the focal species mentioned above, a number of species and one species group were included in the baseline 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:

- Cormorant
- Whooper swan (focal species)
- Tundra swan
- Pink-footed goose (focal species)
- Taiga bean goose (focal species)
- Greylag goose
- Light-bellied brent goose
- Hen harrier
- Buzzard
- Peregrine falcon
- Common crane (focal species)
- Golden plover
- Wood pigeon
- Great grey shrike
- Common raven
- Passerines (corvids, swallows, larks, wagtails, pipits, etc.)
- Nocturnal migrants.

A total list of the bird species registered during the baseline programme is presented in App. A. It should be noted that since the occurrence and, as a result, the amount of data collected for individual species, varies, the level of detail in the analysis differs radically between species. Vulnerable species such as white-tailed eagle and golden eagle were both observed as only one single individual each during the baseline study, and therefore these species could not be subject to further analysis. However, they will be included in the analyses of the future post-construction studies should they occur in significant numbers.

For most species, the distances between flight paths and future structures at the test centre are shown for different distance classes to each type of structure. This information will be used in the post-construction programme to determine the extent to which attraction and avoidance may take place.

Cormorant

General occurrence

In 2011, more than 25,000 breeding pairs of cormorant were registered in Denmark. In Limfjorden, around 1,500 pairs breed within the colony on the island of Melsig in nearby Arup Vejle, this being 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.

Temporal and spatial patterns of occurrence in the study area

Highest numbers of cormorants occurred in late spring. Cormorants also occurred in the study area from September until late October, whereas in winter the birds left the area (Tab. 3).

Table 3. Numbers of cormorants passing the wind farm area on visual transects in late spring (April 29-May 26 2011) and September 2011-February 2012 expressed as observed/calculated number of individuals.

	Late spring	Sep	Oct	Nov	Dec	Jan	Feb
North		68/1586	30/988	0/0	0/0	0/0	0/0
South		64/1514	1/33	0/0	0/0	0/0	0/0
Total	266/14841	132/3100	31/1021	0/0	0/0	0/0	0/0

Most cormorants were observed close to the western (spring) and central (autumn) observation stations. However, more individuals and flocks may have occurred in other parts of the study area as trees obscured the observations in some directions. The north-south orientated flight pattern indicates that the majority of cormorants observed in the study area in spring were breeding birds commuting between the colony at Melsig and feeding areas in western Thy and Skagerrak (Kjeldsen 2008) (Fig. 15,16). The minimum distances between flight paths of cormorants and future structures at the test centre are shown in Fig. 17.

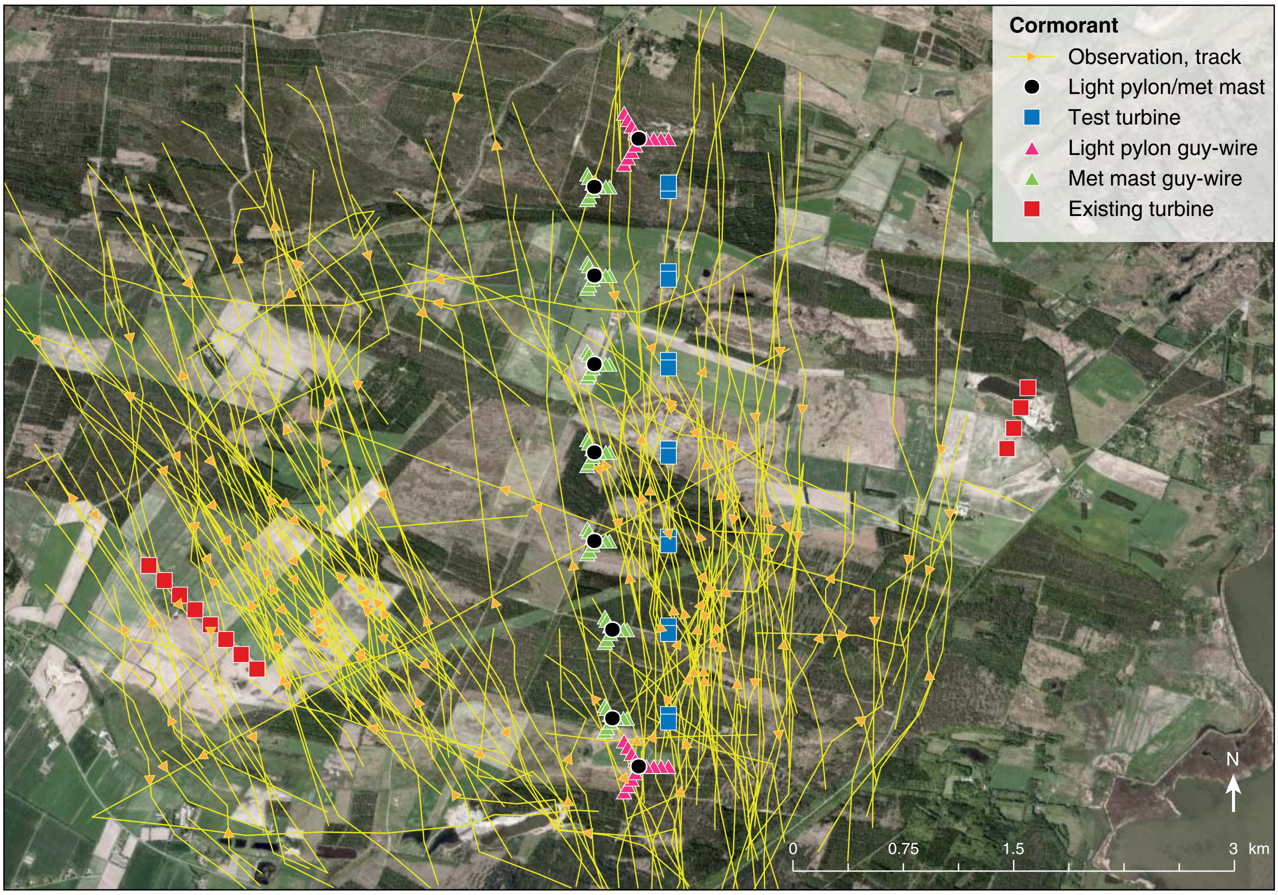
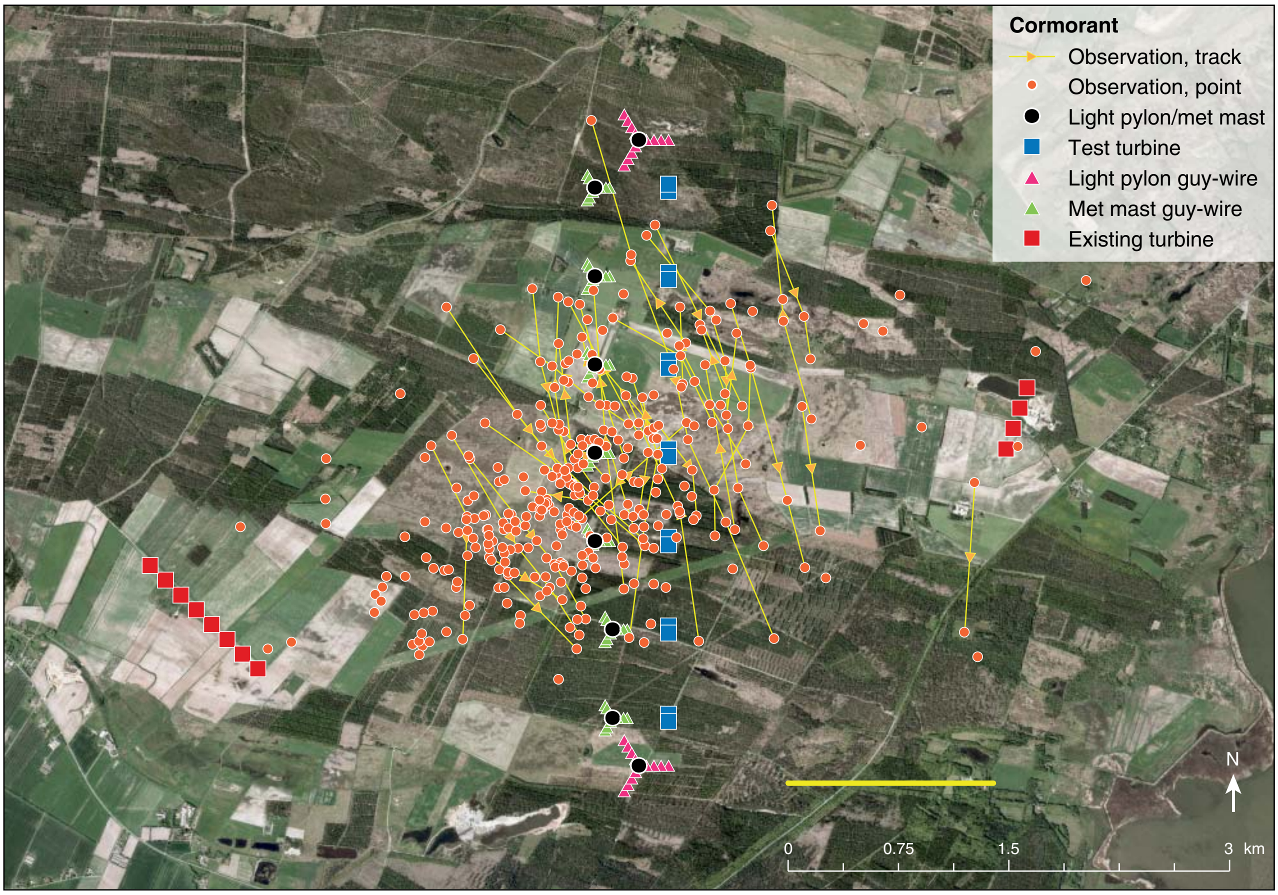


Figure 15. Overall flight patterns of cormorants in the study area, April-May 2011. Data were obtained by measurements with horizontal radar. The yellow arrow indicates the flight direction.



Figur 16. Overall flight patterns of cormorants in the study area, April-May 2011 and September 2011-February 2012. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Yellow arrows indicate the flight direction, and the yellow bar indicates the distance (1,397 m) from the observer within which 90% of the observation points were located.

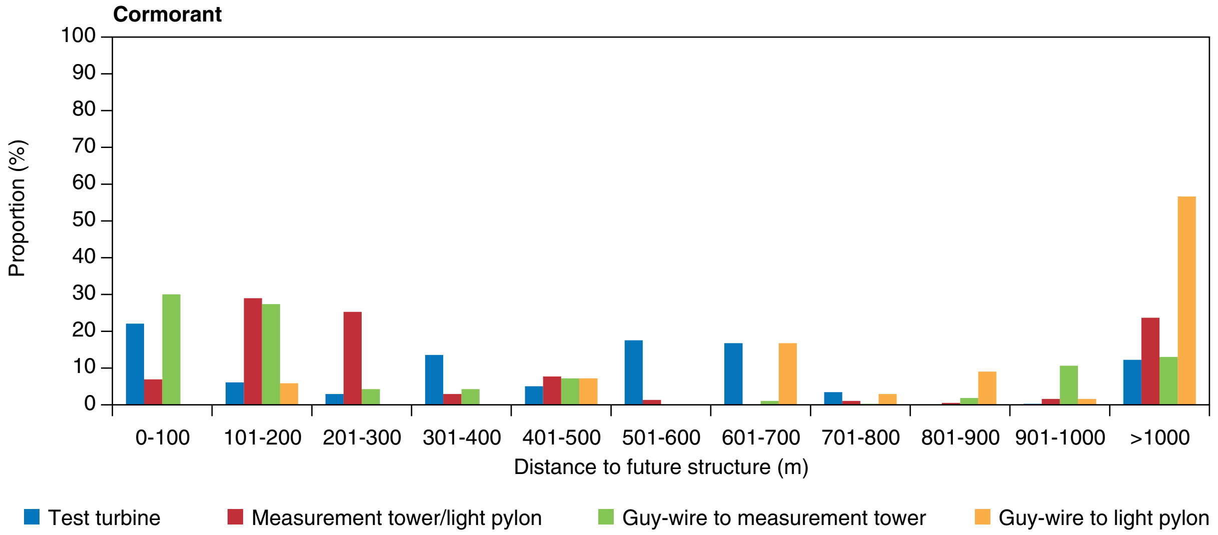


Figure 17. Distribution of minimum distances between flight paths of cormorants and future structures at the test centre, late spring 2011 and September 2011-February 2012. The proportion is weighted by the number of individuals in the observed flocks.

Highest numbers of cormorants occurred in the evening, which was probably a result of flocks returning from feeding areas northwest of the study area. There was a negative relationship between temperature and the occurrence of cormorants in the study area. This was presumably a result of cormorants moving further south along the flyway in late autumn (Tab. 4).

Table 4. Factors affecting the occurrence of cormorants in the study area (N=227 count periods).

Sub-model	Factor	Estimate	SE	Wald χ2	P
Neg. bin. Numbers > 0	TIME evening	3.3178	0.8362	15.74	< 0.0001
	TIME mid-day	-0.8566	0.6981	1.51	0.2198
	TIME morning	0			
	TEMP	-0.2785	0.1072	6.76	0.0093
Logistic	TIME evening	-2.2523	0.7624	8.73	0.0031
	TIME mid-day	-0.7959	0.7821	1.04	0.3088
	TIME morning	0			

Altogether, 74.2% and 78.4% of the observed individuals and flocks, respectively, of cormorants occurred at rotor height (50-250 m), whereas 23.6% and 21.0% of the remainder of individuals and flocks, respectively, were below rotor height (Fig. 18).

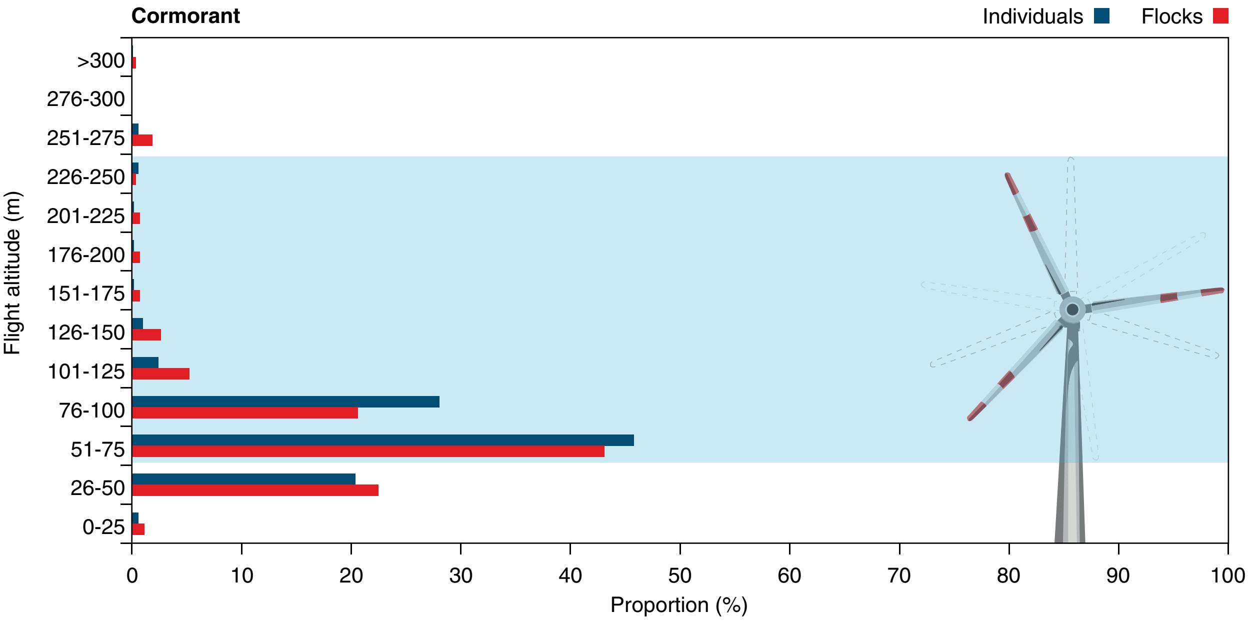
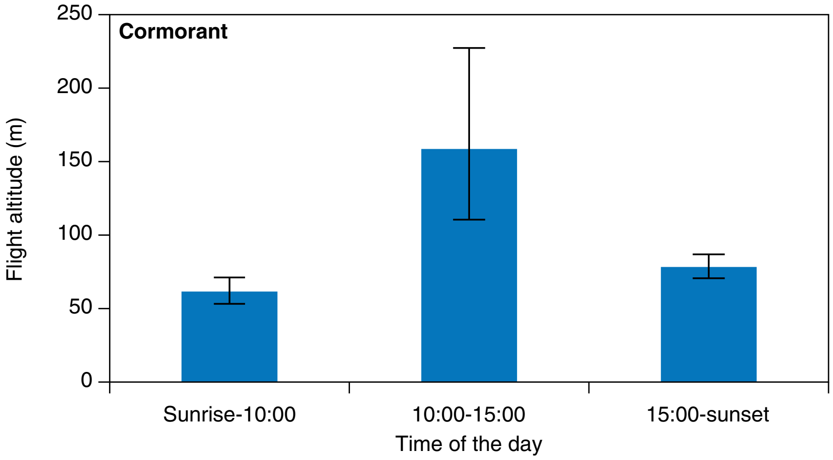


Figure 18. Flight altitudes of cormorants expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.Flight altitudes of cormorants expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.

Flight altitude was highest during the middle of the day. This may be a result of either local birds using thermals to gain height or an influx of real migrants from Norway, which begin to arrive in late August (T. Bregnballe, pers. comm.) (Fig. 19).

Figure 19. The relationship between the time of the day and flight altitudes of cormorants passing the study area in late spring 2011 and September 2011-February 2012.



Preliminary estimate of collision risk at turbines and other structures

A total of three collisions between cormorants and wind turbines are expected to take place in late spring and from September until the end of February. It should be noted that although the period covers most of the annual cycle, no data were collected during any part of the breeding season and late summer. The preliminary estimate of the number of collisions, which is based on a relatively limited amount of data collected during one season, should therefore be interpreted with caution.

We were unable 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.

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

Preliminary assessment

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 cormorants is considered to be insignificant. However, it should be noted that on the basis of the regular occurrence of both breeding and autumn staging individuals in Northwest Jutland, data will 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 Northwest Jutland belong to the Continental Northwest 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) (Fig. 20).

Figure 20. Whooper swans passing the study area. Photo: Jørgen Peter Kjeldsen, ornit.dk.

Temporal and spatial patterns of occurrence in the study area

Whooper swans began to arrive to Northwest Jutland in October and highest numbers were reached in midwinter. Whooper swans were still present in the area in February (Tab. 5).

Table 5. Numbers of whooper swans passing the wind farm area on visual transects in late spring (April 29-May 26 2011) and September 2011-February 2012 expressed as observed/calculated number of individuals.

	Late spring	Sep	Oct	Nov	Dec	Jan	Feb
North		0/0	7/215	20/728	103/3922	57/2164	50/1727
South		0/0	4/132	15/585	13/531	14/593	8/305
Total	0/0	0/0	11/347	25/1313	116/4453	71/2757	58/2033

Most whooper swans were observed close to the central observation station, although flocks were observed 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. 21). The minimum distances between flight paths of whooper swans and future structures at the test centre are shown in Fig. 22.

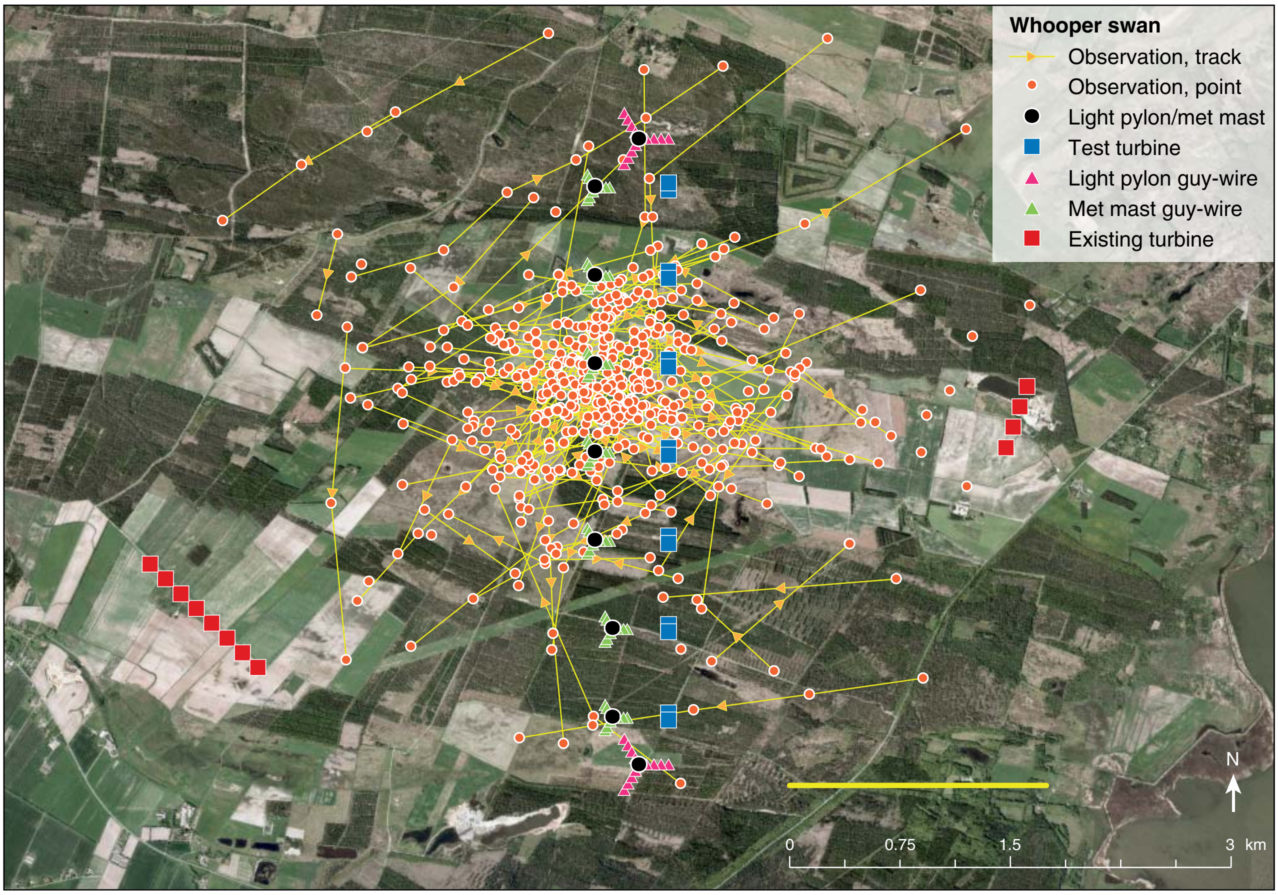


Figure 21. Overall flight patterns of whooper swans in the study area, April-May 2011 and September 2011-February 2012. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Yellow arrows indicate the flight direction, and the yellow bar indicates the distance (1,745 m) from the observer within which 90% of the observation points were located.

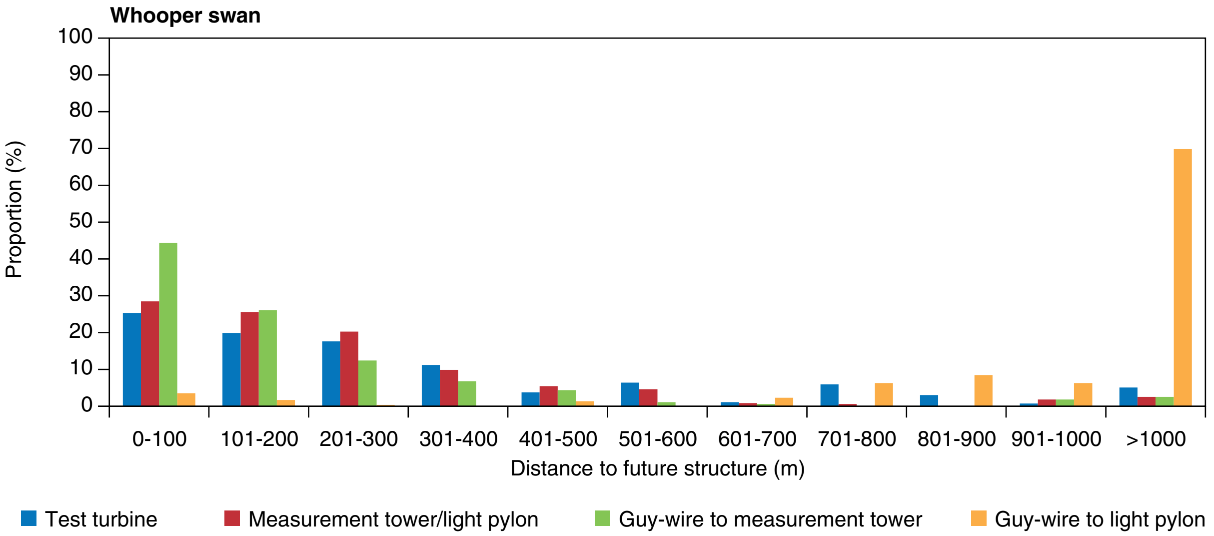


Figure 22. Distribution of minimum distances between flight paths of whooper swans and future structures at the test centre, late spring 2011 and September 2011-February 2012. The proportion is weighted by the number of individuals in the observed flocks.

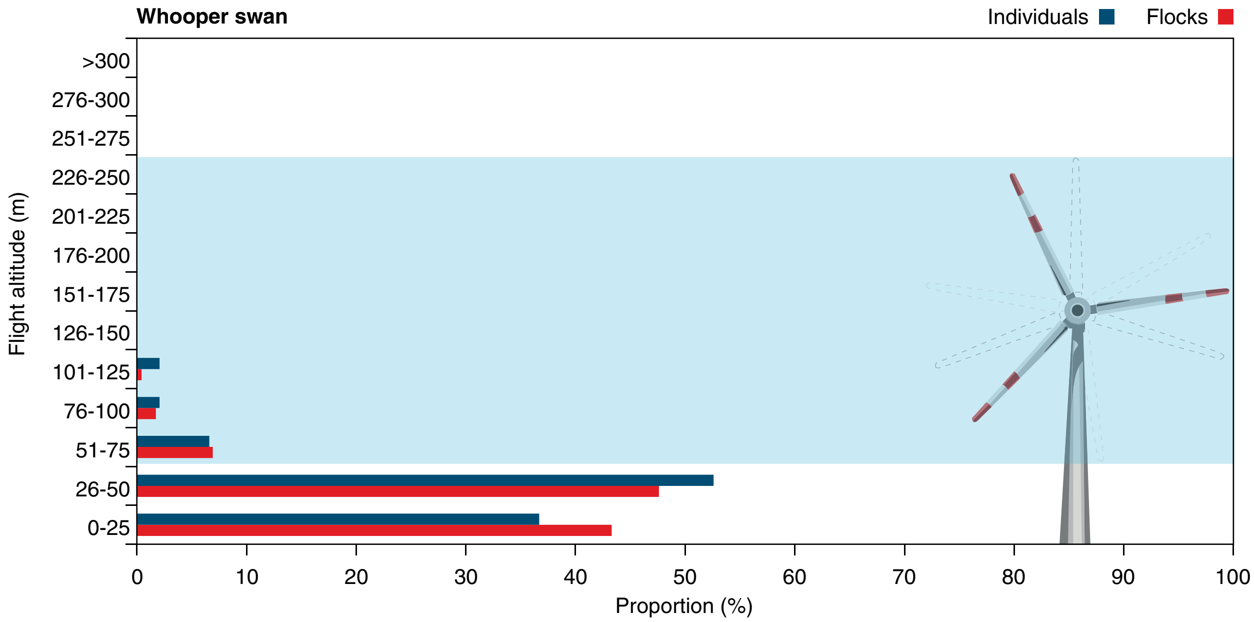


Figure 23. Flight altitudes of whooper swans expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.

Altogether, 9.1% and 10.7% of the observed individuals and flocks, respectively, of whooper swans occurred at rotor height (50-250 m), whereas the remainder were below rotor height (Fig. 23).

Preliminary estimate of collision risk at turbines and other structures

Less than one collision (0.43) between whooper swans and wind turbines is expected to take place in late spring and from September until the end of February. It should be noted that although the period covers most of the annual cycle, no data were collected in March, when whooper swans are still occurring in Northwest Jutland prior to departure to the breeding grounds.

The preliminary estimate of the number of collisions, which is based on a relatively limited amount of data collected during one season, should therefore be interpreted with caution.

There were no indications that seasonal migration took place in the study area and we therefore 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 associated risk of collisions between this species and other structures at the test centre, e.g. guy wires and towers. 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).

Preliminary assessment

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 whoopers is considered to be insignificant. However, it should be noted that on the basis of the regular occurrence of wintering individuals in Northwest Jutland, data will 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

Tundra swans were only registered in the study area October-November, which coincided with the peak migration of this species (Tab. 6).

Table 6. Numbers of tundra swans passing the wind farm area on visual transects in late spring (April 29-May 26 2011) and September 2011-February 2012 expressed as observed/calculated number of individuals.

	Late Spring	Sep	Oct	Nov	Dec	Jan	Feb
North		0/0	24/790	0/0	0/0	0/0	0/0
South		0/0	17/560	14/546	0/0	0/0	0/0
Total	0/0	0/0	41/1350	14/546	0/0	0/0	0/0

Most tundra swans were observed in the northwestern part of the study area (Fig. 24). The minimum distances between flight paths of tundra swans and future structures at the test centre are shown in Fig. 25.

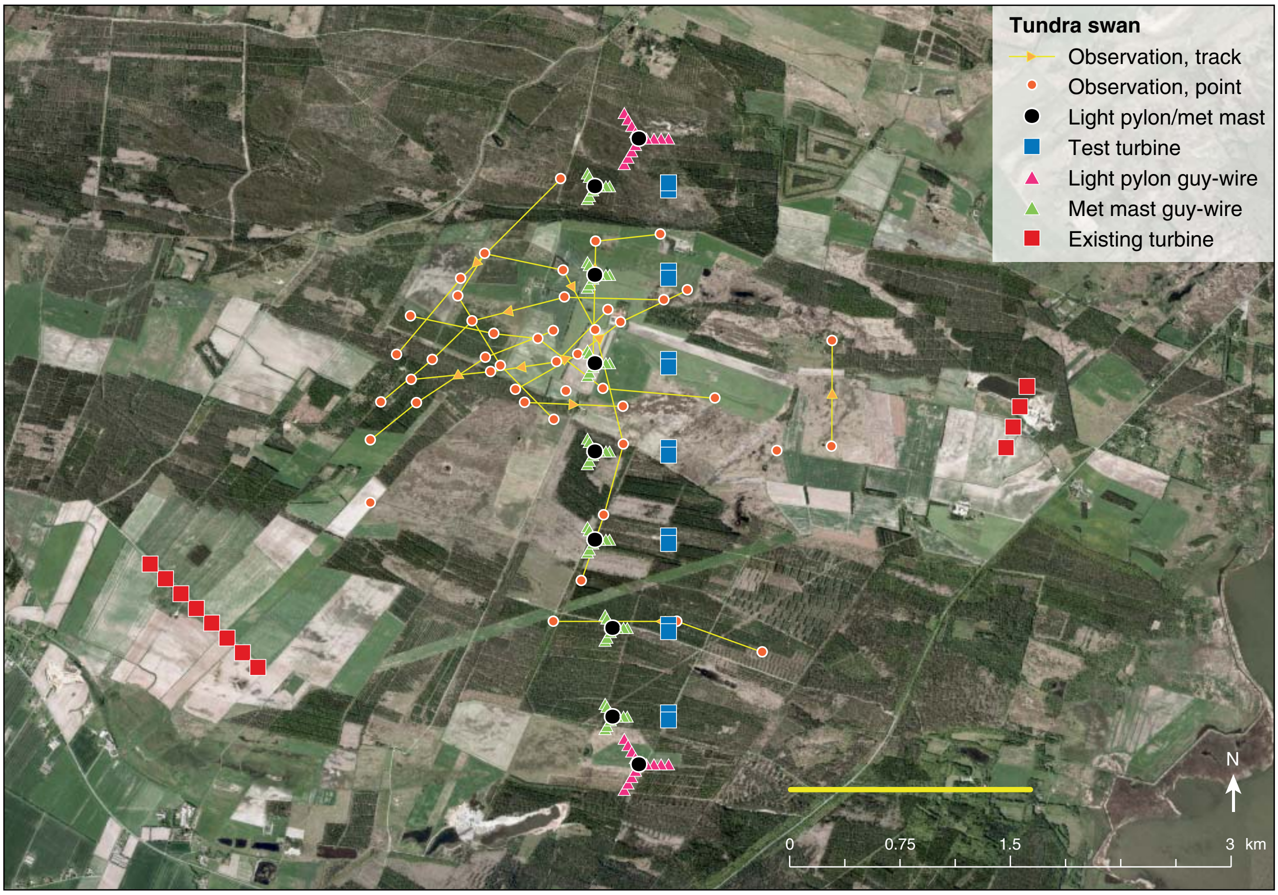


Figure 24. Overall flight patterns of tundra swans in the study area, April-May 2011 and September 2011-February 2012. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow. Yellow arrows indicate the flight direction, and the yellow bar indicates the distance (1,628 m) from the observer within which 90% of the observation points were located.

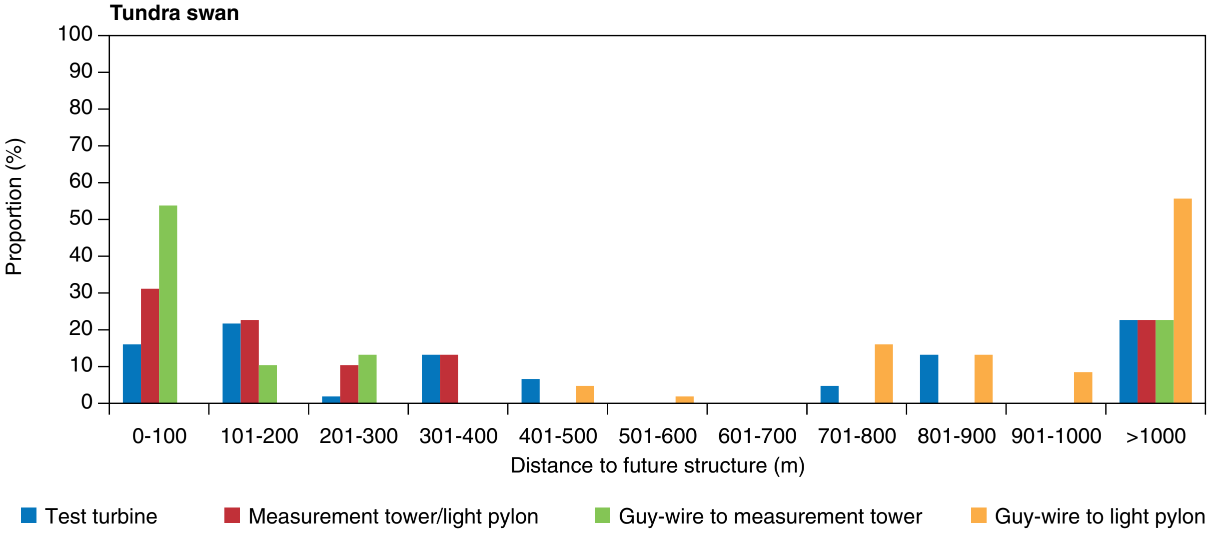


Figure 25. Distribution of minimum distances between flight paths of tundra swans and future structures at the test centre, September 2011-February 2012. The proportion is weighted by the number of individuals in the observed flocks.

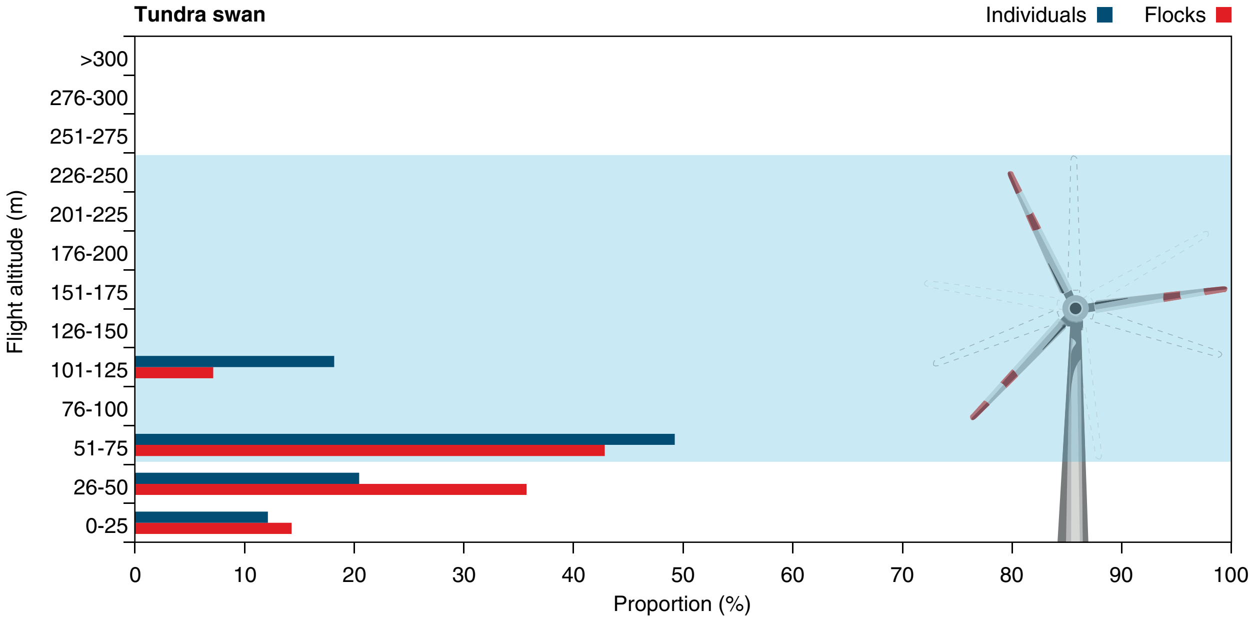


Figure 26. Flight altitudes of tundra swans expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.

Altogether, 50.0% and 67.4% of the observed individuals and flocks, respectively, of tundra swans occurred at rotor height (50-250 m), whereas the remainder were below rotor height (Fig. 26). Thus, flight altitude of tundra swans is considerably higher than the flight altitude of the related whooper swan. This suggests that the tundra swans occurring in the study area is migrating over larger distances than the whooper swans

Preliminary estimate of collision risk at turbines and other structures

Less than one collision (0.42) between tundra swans and wind turbines is expected to take place in late spring and from September until the end of February. It should be noted that although the period covers most of the time during which tundra swans are present in Northwest Jutland, no data were collected in March, when the species stage in the area prior to departure to the breeding grounds.

The preliminary estimate of the number of collisions, which is based on a relatively limited amount of data collected during one season, should therefore be interpreted with caution.

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 towers. This is particularly the case in situations, where visibility is reduced due to adverse weather conditions, or at dusk.

Preliminary assessment

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 tundra swans is considered to be insignificant. However, it should be noted that on the basis of the regular occurrence of spring and autumn staging individuals in Northwest Jutland, data will 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.

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 80,000 individuals (J. Madsen, pers comm.). 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. In addition, GPS-loggers attached to individual pink-footed geese have shown that geese are also commuting between areas at night (M. Chudzinska, in litt.). These daily movements were expected to result in frequent passages in the study area and therefore the baseline programme focused on obtaining high-quality data on the general flight patterns of this focal species.

Temporal and spatial patterns of occurrence in the study area

Pink-footed geese occurred in the study area throughout the study period. The highest number of individuals was registered in October, whereas relatively few pink-footed geese passed the study area in November (Tab. 7).

Table 7. Numbers of pink-footed geese passing the wind farm area on visual transects in late spring (April 29-May 26 2011) and September 2011-February 2012 expressed as observed/calculated number of individuals.

	Late spring	Sep	Oct	Nov	Dec	Jan	Feb
North		42/980	364/11984	19/741	16/653	120/4884	20/741
South		156/2735	3663/89361	15/433	541/16363	742/23271	1418/40121
Total	0/0	198/3714	4027/101345	34/1174	557/1174	862/17016	1438/40861

Flocks of pink-footed geese were registered in most parts of the study area (Fig. 27), although more birds occurred in the southern part (Tab. 7), which probably reflects the short distance to the important staging area Vejlerne situated in a southerly direction. It should be noted that in some directions the view and, hence, the probability of visually detecting low flying flocks, were obstructed by trees. The minimum distances between flight paths of pink-footed geese and future structures at the test centre in late spring and from September until the end of February are shown in Fig. 28 and Fig. 29, respectively.

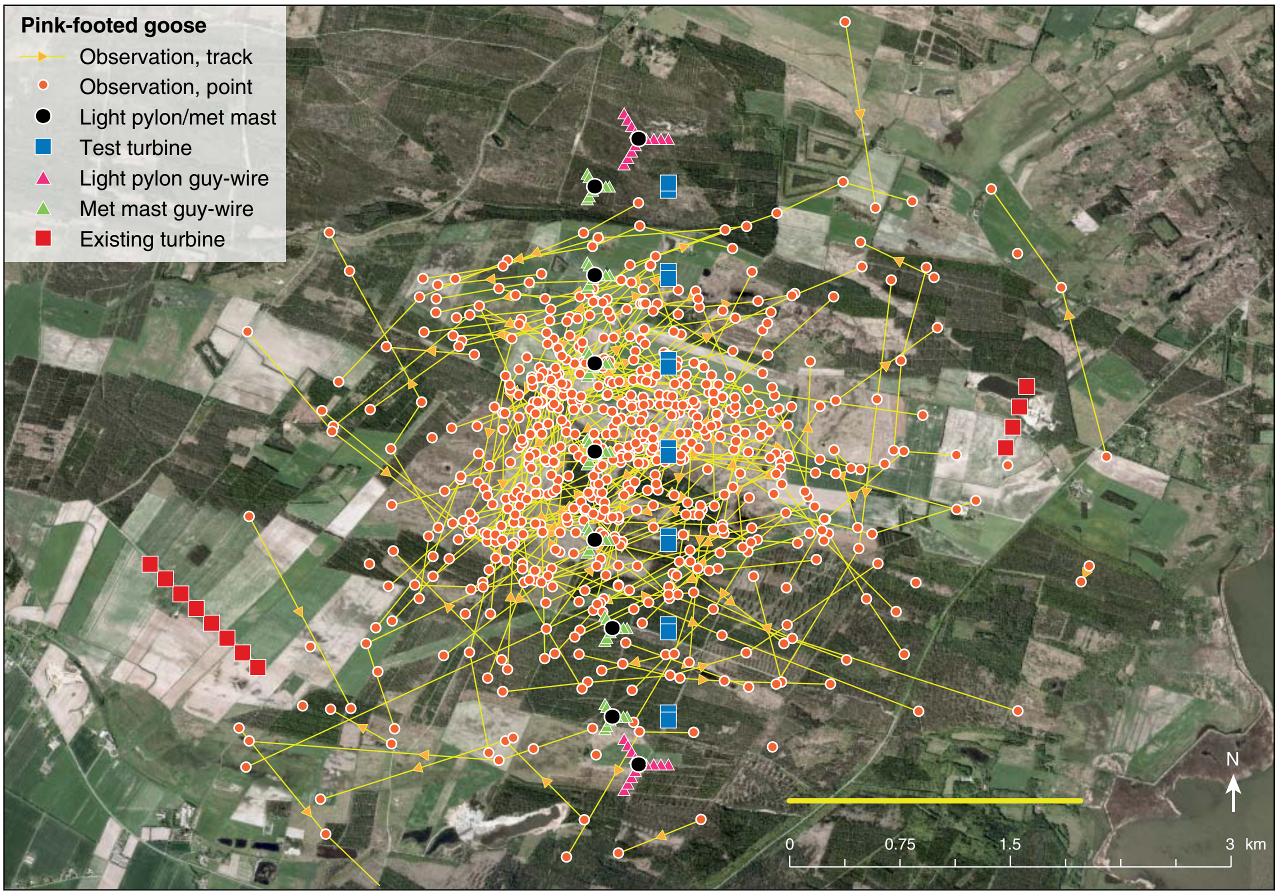


Figure 27. Overall flight patterns of pink-footed geese in the study area, April-May 2011 and September 2011-February 2012. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow. Yellow arrows indicate the flight direction, and the yellow bar indicates the distance (1,980 m) from the observer within which 90% of the observation points were located.

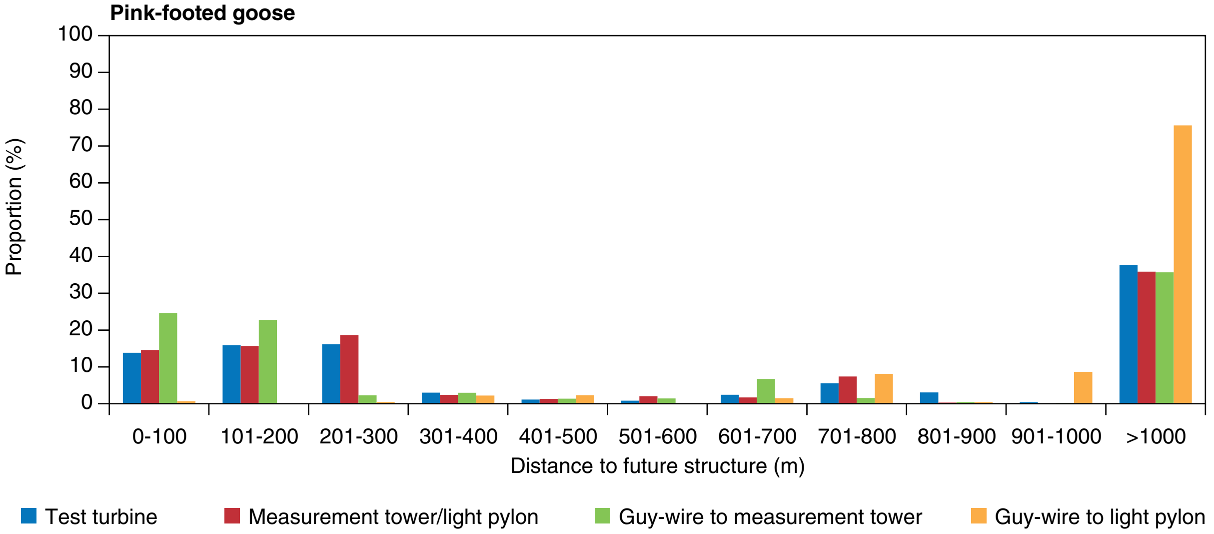


Figure 28. Distribution of minimum distances between flight paths of pink-footed geese and future structures at the test centre, September 2011-February 2012. The proportion is weighted by the number of individuals in the observed flocks.

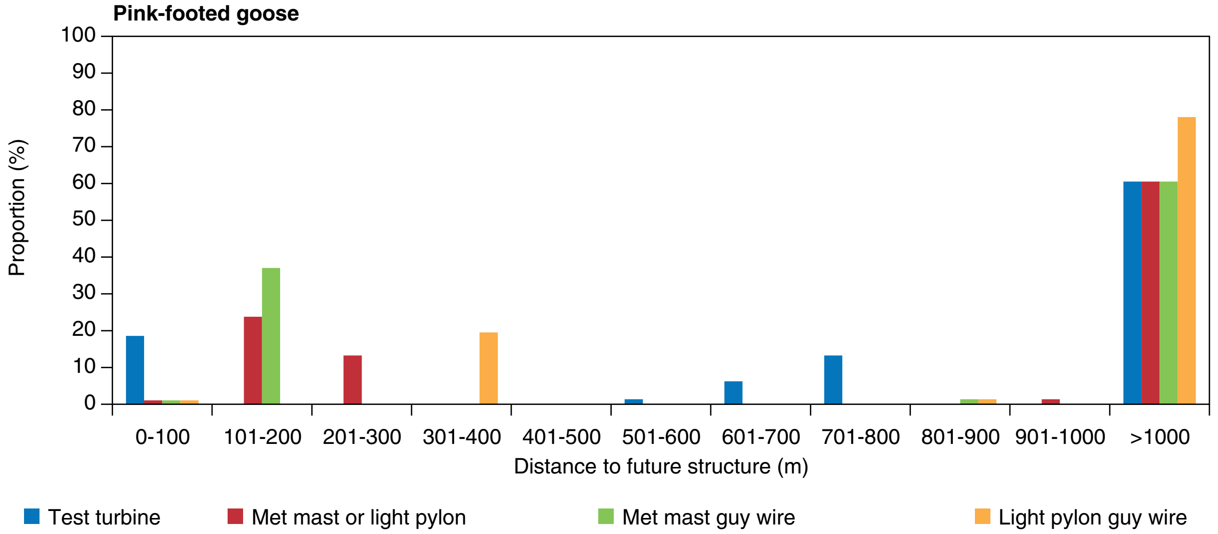


Figure 29. Distribution of minimum distances between flight paths of pink-footed geese and future structures at the test centre, April-May 2011. The proportion is weighted by the number of individuals in the observed flocks.

Most observations of pink-footed geese took place in the morning, which indicates that the study area is situated close to the migration route between roost sites and feeding areas. In the evening, the return flight to the roost areas is probably more broad-fronted, resulting in fewer observations of pink-footed geese passing the study area. Migration intensity was positively correlated to temperature, i.e. pink-footed geese were observed more often in autumn compared to the winter (Tab. 8).

Table 8. Factors affecting the occurrence of pink-footed geese in the study area (N=250 count periods).

Sub-model	Factor	Estimate	SE	Wald $\chi 2$	P
Normal. Numbers > 0	No significant factors				
Logistic	TIME, morning	0			
	TIME, evening	-1.3877	0.5262	6.96	0.0084
	TIME, mid-day	-0.6494	0.3949	2.7	0.1001
	TEMP	0.1887	0.0474	15.85	< 0.0001

Altogether, 72.9% and 83.2% of the observed individuals and flocks, respectively, of pink-footed goose occurred at rotor height (50-250 m) (Fig. 30). It should be noted that most observations were made during periods with favourable weather conditions, where flight height is expected to be higher than during periods with adverse weather conditions.

The flight altitude of pink-footed geese passing the study areas was reduced during poor visibility (Fig. 31) and strong winds (Tab. 9). This means that in periods with adverse weather situations, where collision risk would otherwise be expected to be higher, fewer pink-footed will pass the sweep area of the wind turbines.

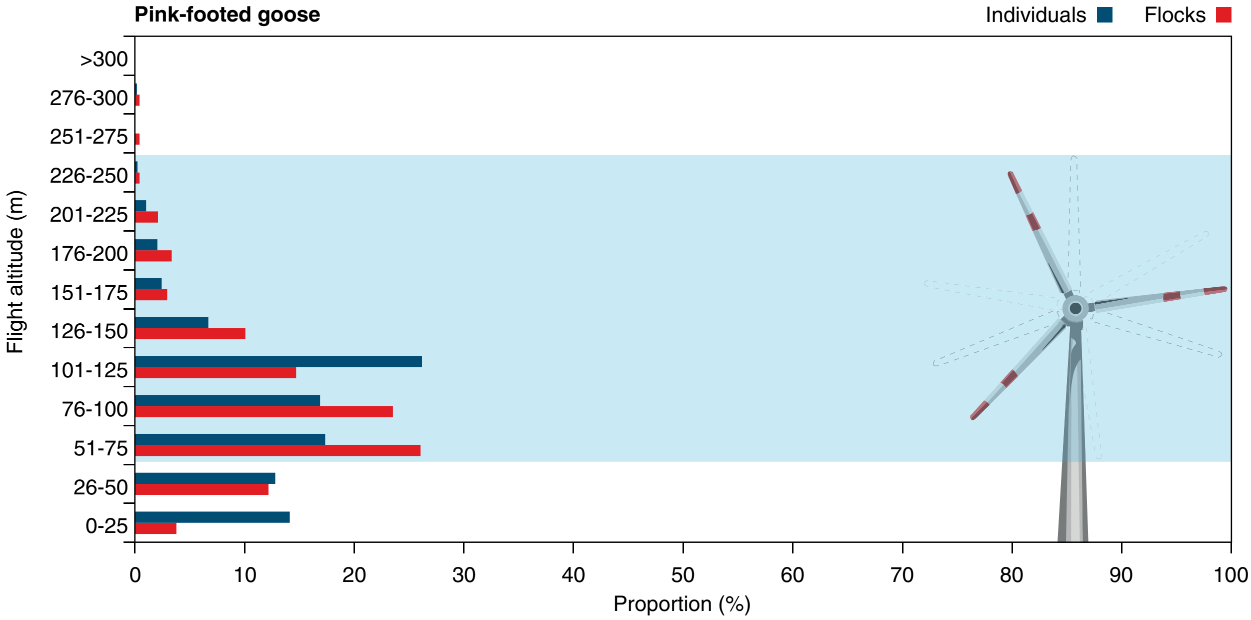
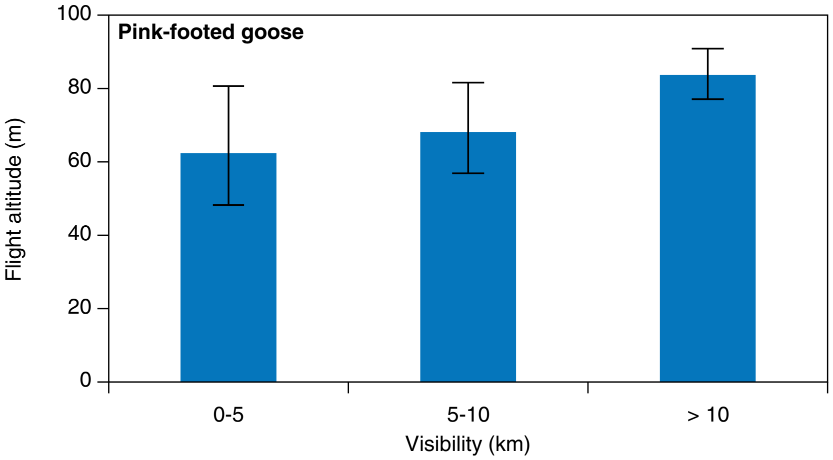


Figure 30. Flight altitudes of pink-footed geese expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.

Figure 31. The relationship between visibility and flight altitude for pink-footed geese passing the study area.



Flight altitude of pink-footed geese was positively correlated to temperature (Tab. 9). This may be a result of more hunting taking place in early autumn, which would be expected to increase flight altitude at this time of the year (see Kahlert et al. 2010). Alternatively, since genuine seasonal migration is expected to take place at higher altitude than daily movements between feeding areas and roosts, a larger proportion of real migrants among the flocks observed in early autumn may also explain this pattern.

Table 9. Factors affecting the flight altitude of pink-footed geese in the study are (N=223 flocks, r^2=0.12).

Factor	Estimate	SE	t	P
VISIB 1-5 km	-0.6774	0.1528	4.52	< 0.0001
VISIB 5-10 km	-0.2067	0.1044	1.98	0.0489
VISIB > 10 km	0			
TEMP	0.043	0.009	4.74	< 0.0001
SPEED	-0.0245	0.0106	2.31	0.0215

Preliminary estimate of collision risk at turbines and other structures

Estimated 21-46 collisions between pink-footed geese and wind turbines are expected to take place from September until the end of February. This is based on an observed avoidance of 97.75%, which was obtained from a comparable study at nearby Klim Fjordholme and a theoretical avoidance rate of 99% closer to the estimates found in other goose studies (Kahlert et al. 2010). It should be noted that 1) although the period covers most of the time during which pink-footed geese are present in the area, no data were collected from March until late April 2012, when pink-footed geese still occurred in the study area, and that 2) 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. Thus, at nearby Klim Fjordholme, pink-footed geese increased their flight height in autumn, which was probably a result of hunting taking place at this time (Kahlert et al. 2010). Kahlert & Therkildsen (2012) found that pink-footed geese tended to be more active around and just before dawn. This observation combined with the fact that 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 associated risk of collisions between this species and other structures at the test centre, e.g. guy wires and towers. The preliminary estimate of the number of collisions, which is based on a relatively limited amount of data collected during one season, should therefore be interpreted with caution.

Preliminary assessment

The estimated collision frequency corresponds to 0.026-0.058% of the total Svalbard breeding population, which amounts to 80,000 individuals, and to 0.13-0.29% of the maximum number of individuals (c. 16,000 according to DOFbasen) observed in Northwest Jutland during 2007-2011. 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 the Svalbard and regional reference populations of pink-footed goose is considered to be insignificant. 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 SPA’s to a lesser or greater extent. On the basis of the regular occurrence in the study area, 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 a small sub-population breeding in central Sweden. With the onset of cold weather and snow, the flocks migrate to 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 in September 2011 and from January until the end of February 2012. The highest number of individuals was registered in January 2012, whereas the absence from October until December 2011 may reflect the fact that some of the flocks continued their migration to the wintering grounds in eastern Britain, whereas others spent the winter further west in Thy (Tab. 10).

Table 10. Numbers of taiga bean geese passing the wind farm area on visual transects in late spring (April 29-May 26 2011) and September 2011-February 2012 expressed as observed/calculated number of individuals.

	Late spring	Sep	Oct	Nov	Dec	Jan	Feb
North		76/1418	0/0	0/0	0/0	9/293	3/89
South		0/0	0/0	0/0	0/0	43/1365	0/0
Total	0/0	76/1418	0/0	0/0	0/0	52/1658	3/89

Most of the taiga bean geese were tracked near the observation station in the central open part of the study area. This may reflect the fact that the geese preferred the cultivated strips and that the view in some parts of the study area was hampered by trees. The majority of flocks moved in an east-westerly direction (Fig. 32), which indicates that the bean geese observed in the study area were autumn staging and wintering flocks commuting between roosts and feeding areas. The minimum distances between flight paths of taiga bean geese and future structures at the test centre are shown in Fig. 33.

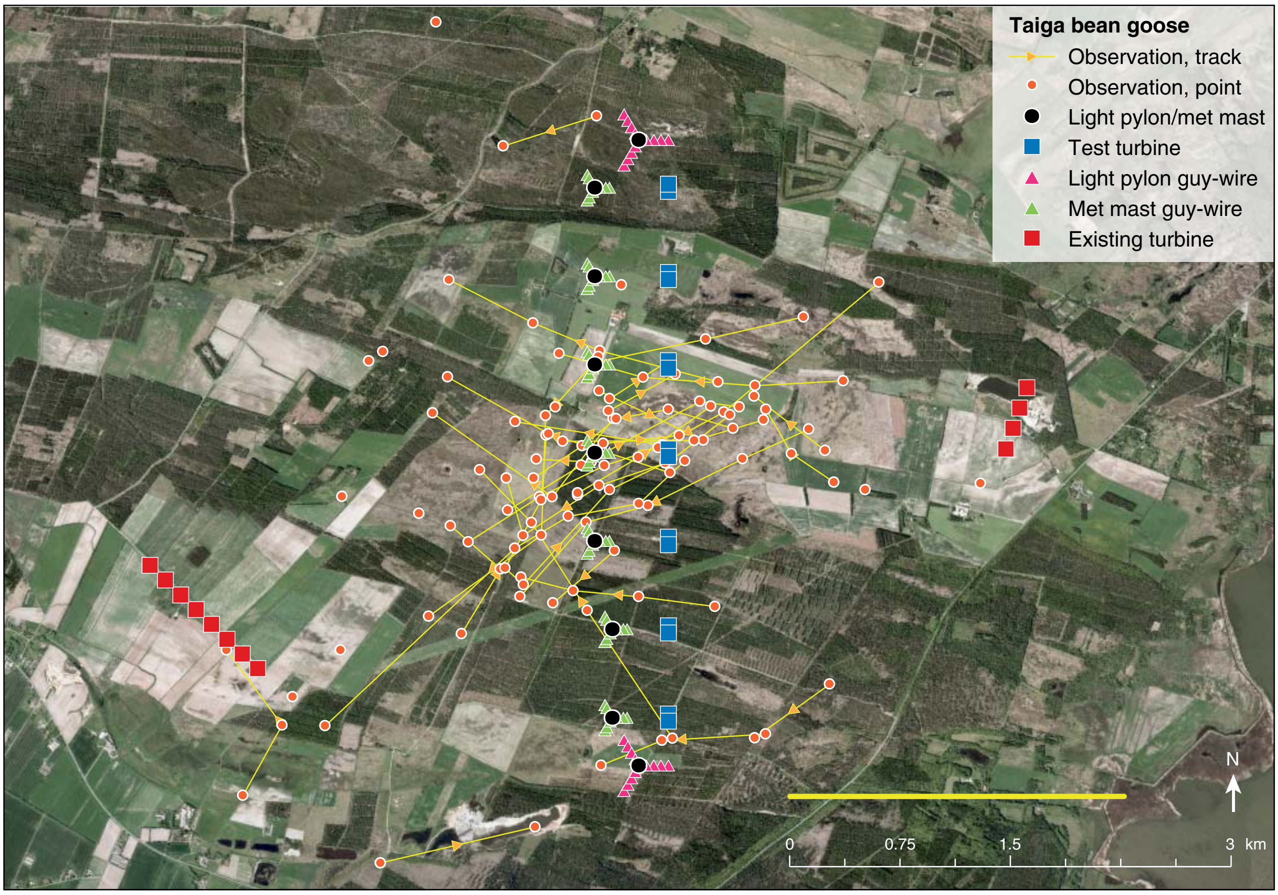


Figure 32. Overall flight patterns of taiga bean geese in the study area, April-May 2011 and September 2011-February 2012. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Yellow arrows indicate the flight direction, and the yellow bar indicates the distance (2,271 m) from the observer within which 90% of the observation points were located.

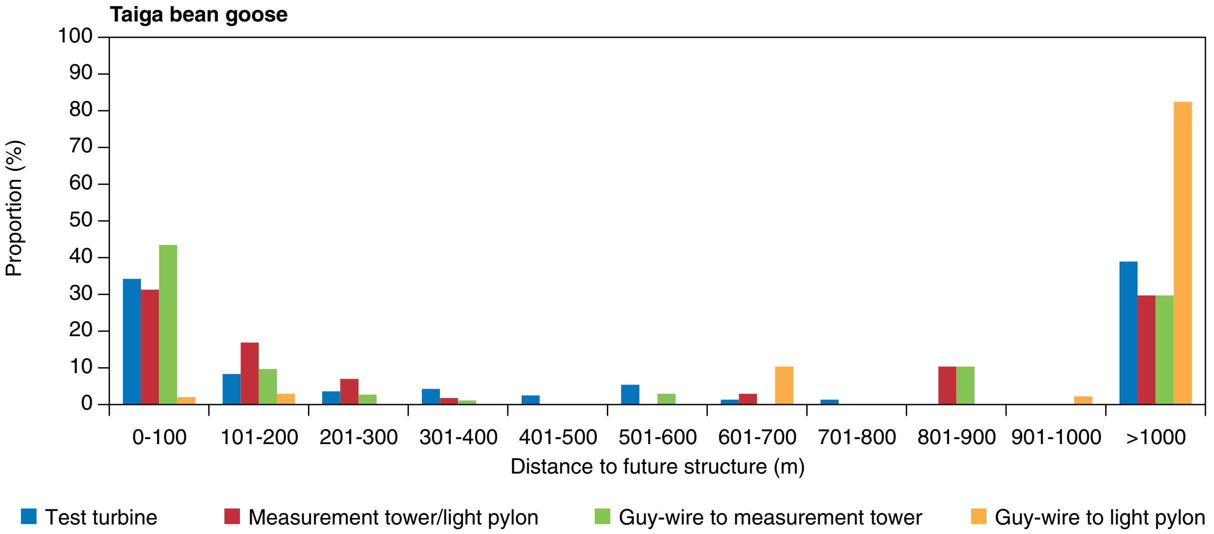


Figure 33. Distribution of minimum distances between flight paths of taiga bean geese and future structures at the test centre, September 2011-February 2012. The proportion is weighted by the number of individuals in the observed flocks.

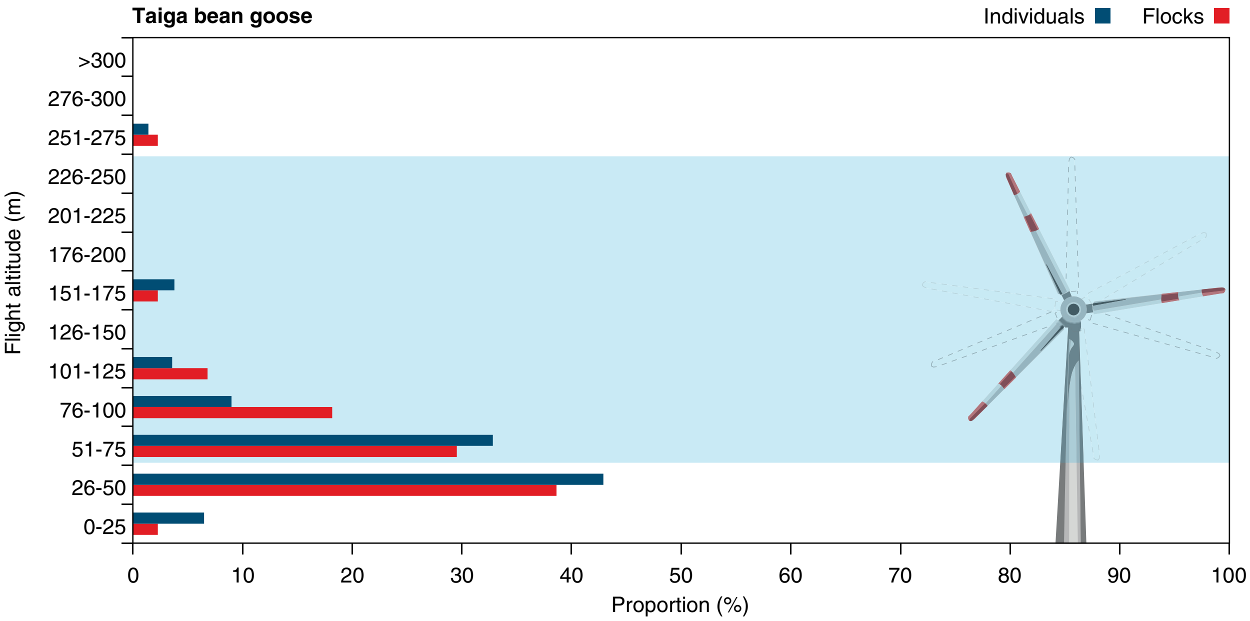


Figure 34. Flight altitudes of taiga bean geese expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.

Altogether, 56.8% and 49.2% of the observed individuals and flocks, respectively, of bean geese occurred at rotor height (50-250 m), whereas 40.9% and 49.4% of the remainder of individuals and flocks, respectively, were below rotor height (Fig.45).

Preliminary estimate of collision risk at turbines and other structures

Less than one (0.22) collision between taiga bean geese and wind turbines is expected to take place in late spring and from September until the end of February.

The data collected during the baseline programme 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 & Therkildsen 2012), 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 towers. This is particularly the case in situations, when visibility is reduced due to adverse weather conditions.

It should be noted that although the observation period covers most of the time during which taiga bean geese are present in Northwest Jutland, no data were collected in March, when bean geese are still present in the area prior to their departure to the breeding grounds. The preliminary estimate of the number of collisions, which is based on a relatively limited amount of data collected during one season, should therefore be interpreted with caution.

Preliminary assessment

Although the calculated number of collisions must be regarded as a crude estimate, the potential impact of the structures at the test centre on the sub-population 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 absent from the study area in late spring, which may indicate that during the breeding season, greylag geese remain close to the breeding site or use other flight routes than in autumn (Tab. 11). Most greylag geese were observed in September 2011, which was probably a result of the continued presence of the regional breeding population and an influx of migrants from Norway. In late autumn, the geese migrated southwards along the flyway. In January and February 2012, greylag geese returned from the wintering grounds.

Table 11. Numbers of greylag geese passing the wind farm area on visual transects in late spring (April 29-May 26 2011) and September 2011-February 2012 expressed as observed/calculated number of individuals.

	Late spring	Sep	Oct	Nov	Dec	Jan	Feb
North		69/1368	14/392	0/0	0/0	2/69	66/2077
South		774/14978	15/404	0/0	0/0	17/589	65/2030
Total	0/0	843/16346	29/796	0/0	0/0	19/658	131/4107

Most of the greylag geese were observed near the observation station in the central part of the study area. The majority of flocks moved in an east-west direction (Fig. 35), which indicates that the greylag geese observed in the study area were autumn staging and wintering flocks commuting between roosts and feeding areas. The minimum distances between flight paths of greylag geese and future structures at the test centre are shown in Fig. 36.

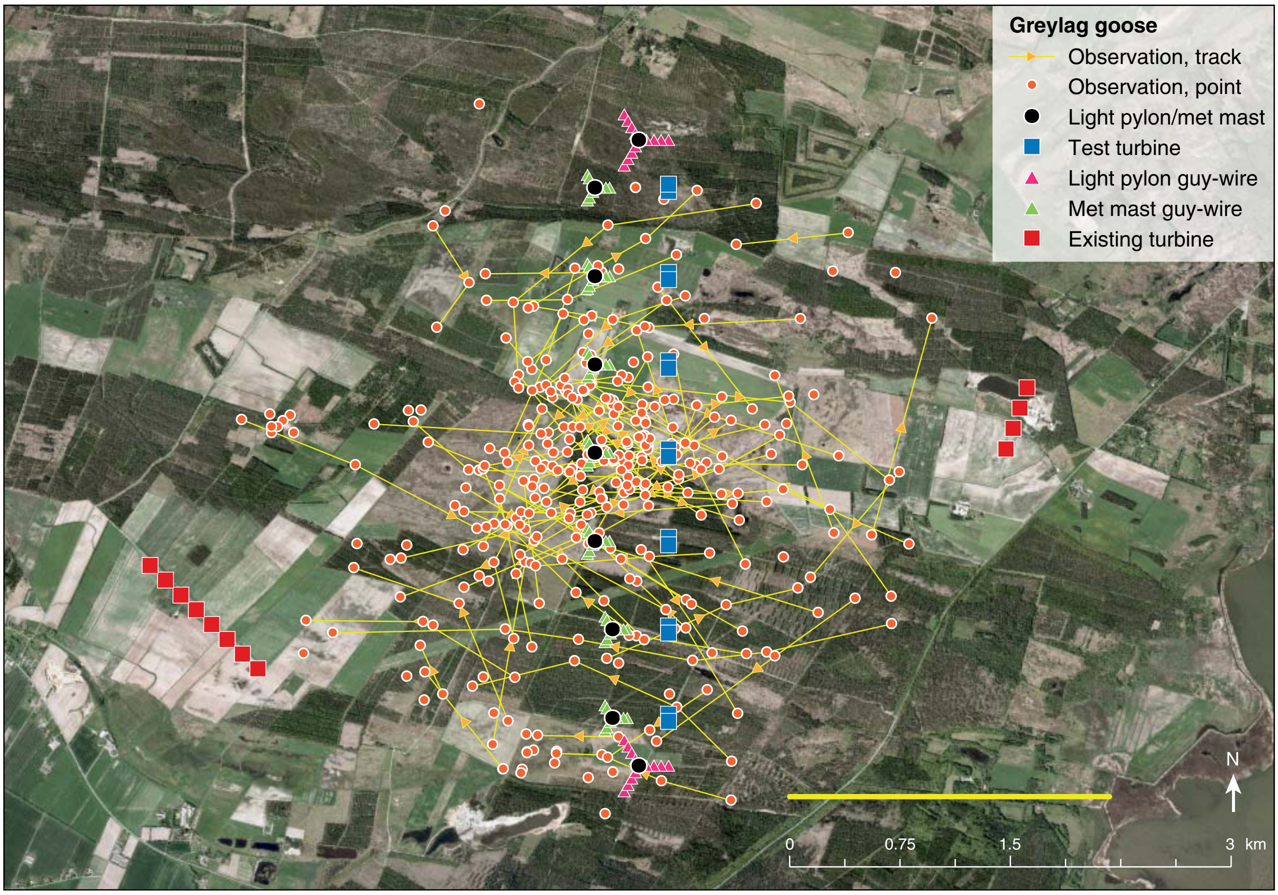


Figure 35. Overall flight patterns of greylag geese in the study area, April-May 2011 and September 2011-February 2012. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Yellow arrows indicate the flight direction, and the yellow bar indicates the distance (2,173 m) from the observer within which 90% of the observation points were located.

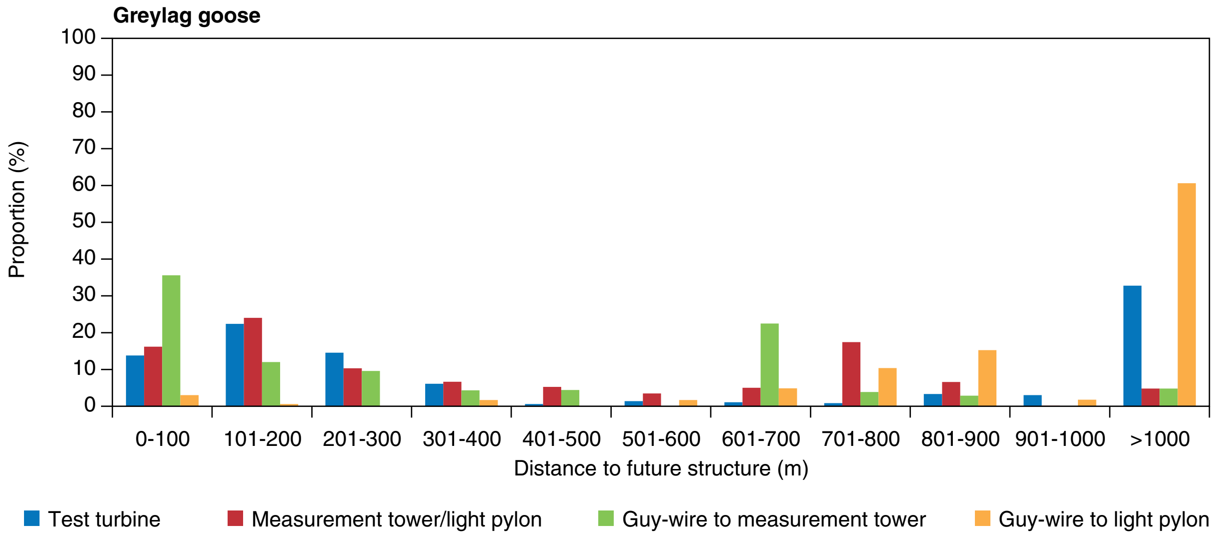


Figure 36. Distribution of minimum distances between flight paths of greylag geese and future structures at the test centre, September 2011-February 2012. The proportion is weighted by the number of individuals in the observed flocks.

Most greylag geese were observed in the morning, which is probably a result of regular movements between night roosts and feeding areas at this time of the day. There was a positive correlation between cloud cover and the occurrence of greylag geese in the study area, although this pattern is difficult to interpret (Tab. 12).

Table 12. Factors affecting the occurrence of greylag geese in the study area (N=206 count periods).

Sub-model	Factor	Estimate	SE	Wald χ2	P
Neg. bin. Numbers > 0	CLOUD	0.1801	0.0614	8.6	0.0034
Logistic	TIME, morning	1.3786	0.4568	9.11	0.0025
	TIME, evening	0.0738	0.4644	0.03	0.8737
	TIME, mid-day	0			

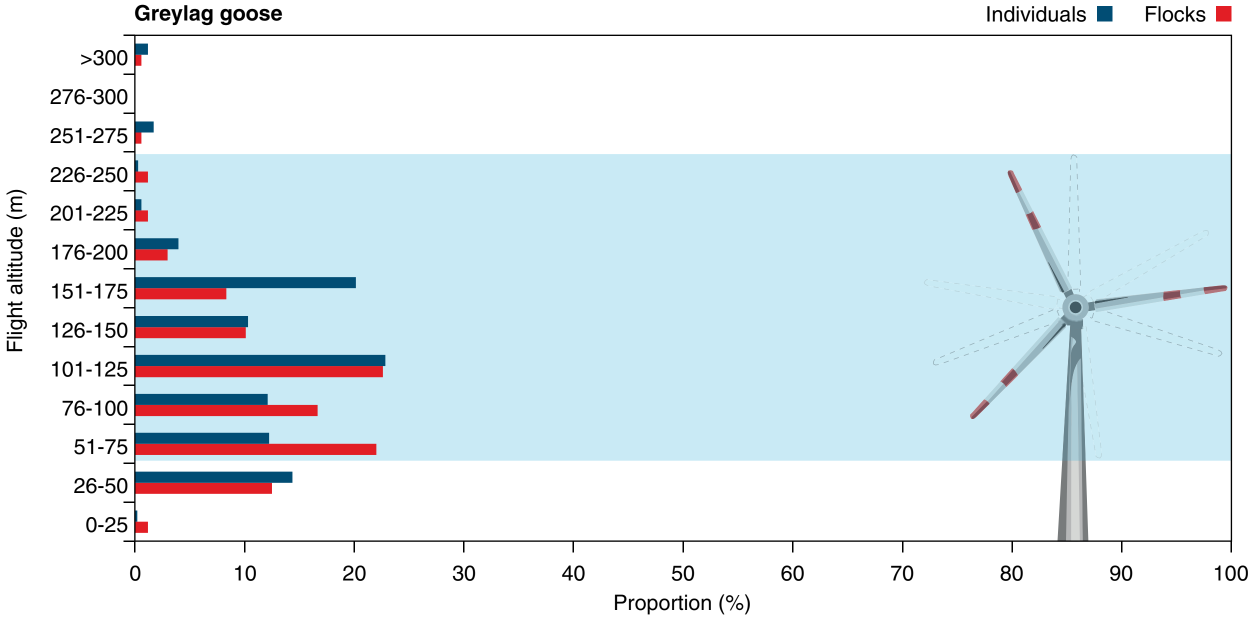


Figure 37. Flight altitudes of greylag geese expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.

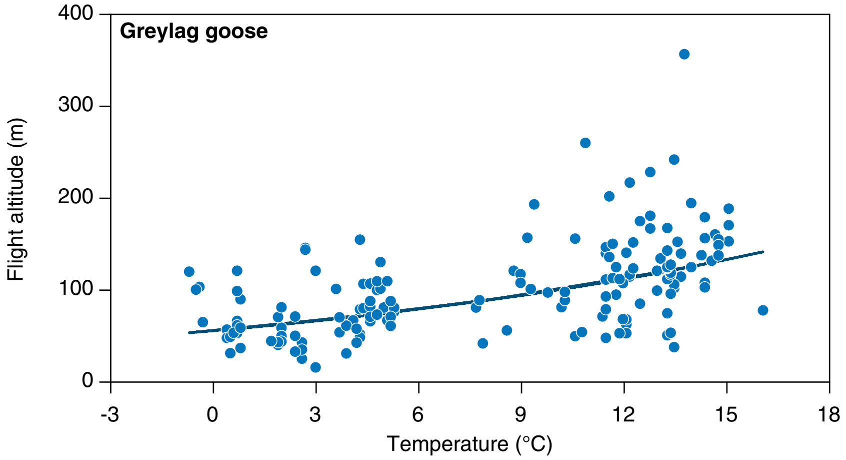
Altogether, 85.1% and 82.5% of the observed individuals and flocks, respectively, of greylag geese occurred at rotor height (50-250 m), whereas 13.7% and 14.6% of the remainder of individuals and flocks, respectively, were below rotor height (Fig. 37).

The flight altitude of greylag geese was positively correlated to the mean daily temperature (Tab. 13, Fig. 38). This may be a result of more hunting taking place in early autumn, which would be expected to increase flight altitude at this time of the year. Alternatively, since seasonal migration is expected to take place at higher altitude than daily movements between feeding areas and roosts, a larger proportion of real migrants among the flocks observed in early autumn, may explain this pattern.

Table 13. Factors affecting the flight altitude of greylag geese in the study are (N=158 flocks, r^2=0.32).

Factor	Estimate	SE	t	P
TEMP	0.0572	0.0066	8.64	< 0.0001

Figure 38. The relationship between flight altitude of greylag geese occurring in the study area and temperature (trendline: y =exp(4.0396-(0.0572*temp))-1).



Preliminary estimate of collision risk at turbines and other structures

An estimated 3-6 collisions between greylag geese and wind turbines are expected to take place in late spring and from September until the end of February. For comparison, in recent years more than 50,000 greylag geese stage in West Jutland during autumn.

It should be noted that although the period covers most of the time during which greylag geese are present in Northwest Jutland, no data were collected in March, where breeding birds are present in Vejlerne and some migrants are still present in the area prior to their departure to the breeding grounds in Norway. Likewise, during summer, when the breeding population is still present in the area, no data is available. The preliminary estimate of the number of collisions, which is based on a relatively limited amount of data collected during one season, should therefore be interpreted with caution.

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 associated risk of collisions between greylag geese and other structures at the test centre, e.g. guy wires and towers. This is particularly the case in situations, where visibility is reduced due to adverse weather conditions.

Preliminary assessment

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 considered to be insignificant. However, it should be noted that on the basis of the regular occurrence of both breeding and autumn staging individuals in Northwest Jutland, data will 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

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 (Fig. 39). The 279 individuals belong to the East-Atlantic flyway population of light-bellied brent geese, which breeds on Svalbard and NE-Greenland (Pihl et al. 2006). In spring, the majority of this population stage in the western part of Limfjorden and the observation coincided with the northbound mass departure, which normally takes place under favourable wind conditions (e.g. tail-winds from a southerly direction) (Clausen et al. 2003).

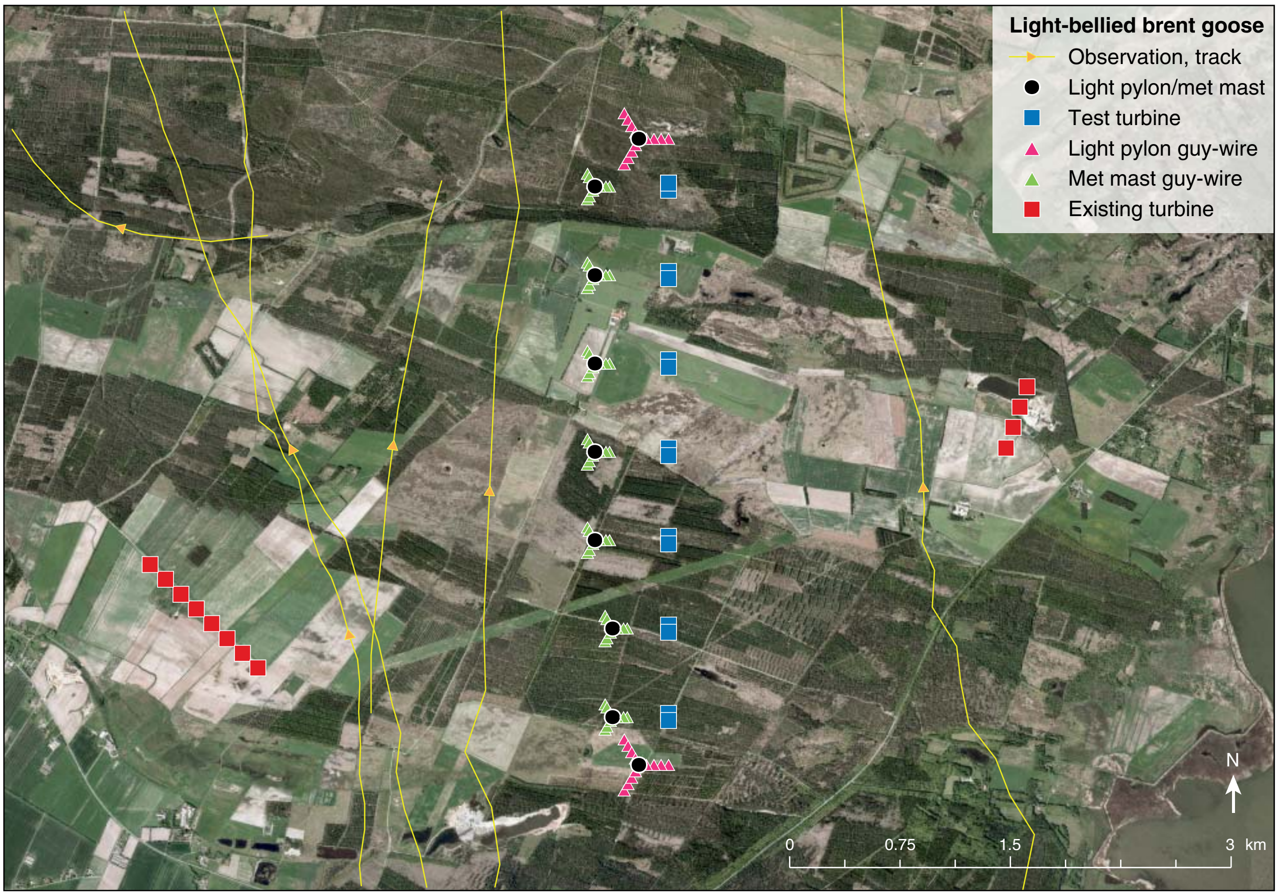


Figure 39. Flight patterns of six flocks of light-bellied brent geese migrating northwards on May 26 2011. Data were obtained by measurements with horizontal radar. Yellow arrows indicate the flight direction.

The flight altitude of the flock of 60 individuals was measured to 205 m (laser range finder) and 251 (vertical radar), whereas the flight altitude of the flock of 57 individuals was measured to 172 m (laser range finder). This means that both flocks occurred within rotor height (50-250 m).

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 279 individuals passing the study area correspond to 3.7-4.7% 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 extra mortality.

The amount of data collected during the baseline programme is not sufficient to perform analyses for a preliminary assessment. For instance, even though 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. On this basis, the species will be included in the post-construction programme as a focal species given its high conservation status.

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

Hen harriers were observed in October and November near the observation station in the central part of the study area (Tab. 14, Fig. 40). To some extent this may reflect difficulties detecting low-flying individuals at longer distances and that the view was obstructed by trees in some directions.

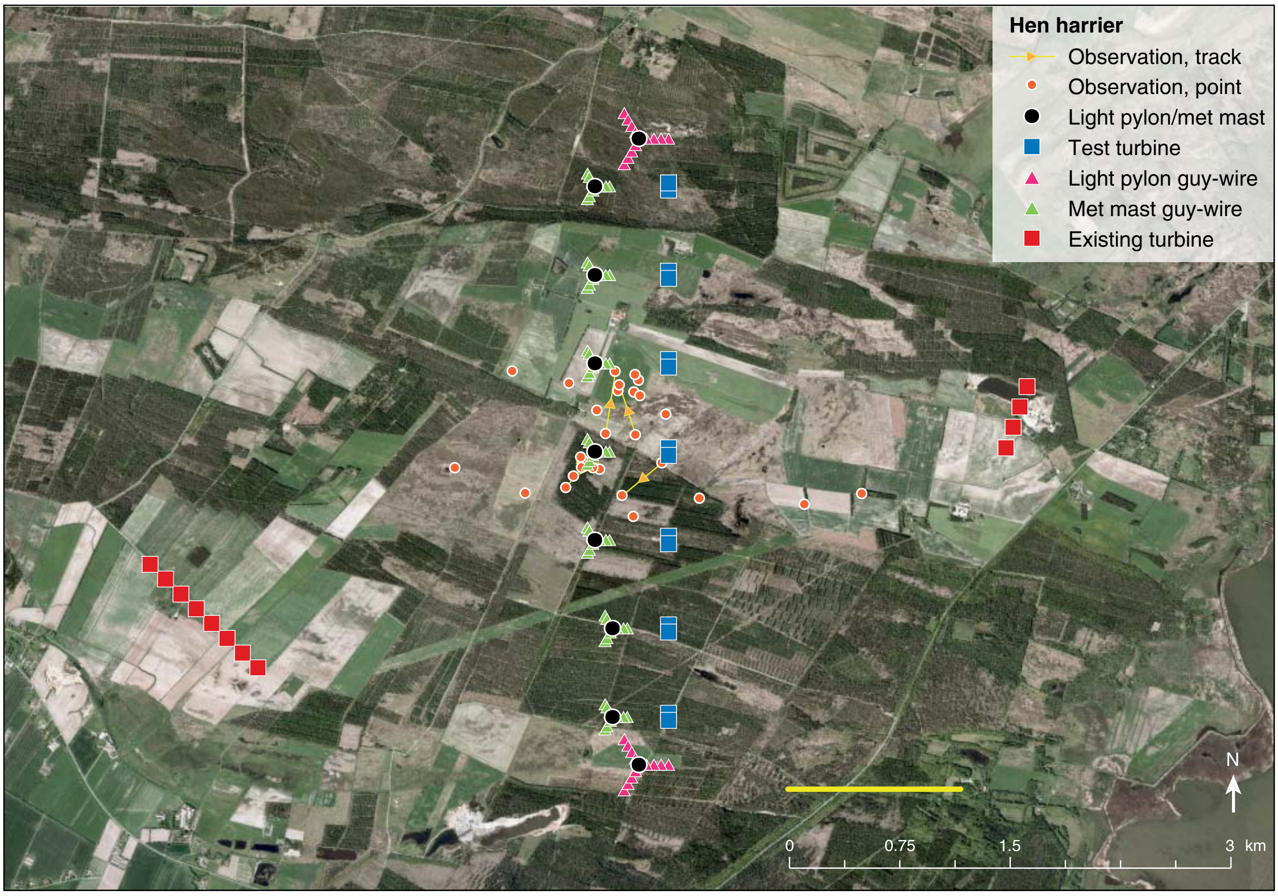


Figure 40. Overall flight patterns of hen harriers in the study area, April-May 2011 and September 2011-February 2012. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Yellow arrows indicate the flight direction, and the yellow bar indicates the distance (1,173 m) from the observer within which 90% of the observation points were located.

The hen harriers observed in the study area were probably autumn staging individuals of unknown origin.

Altogether, 90.5% and 91.3% of the observed individuals and flocks of hen harriers occurred below rotor height (50-250 m) (Fig. 41).

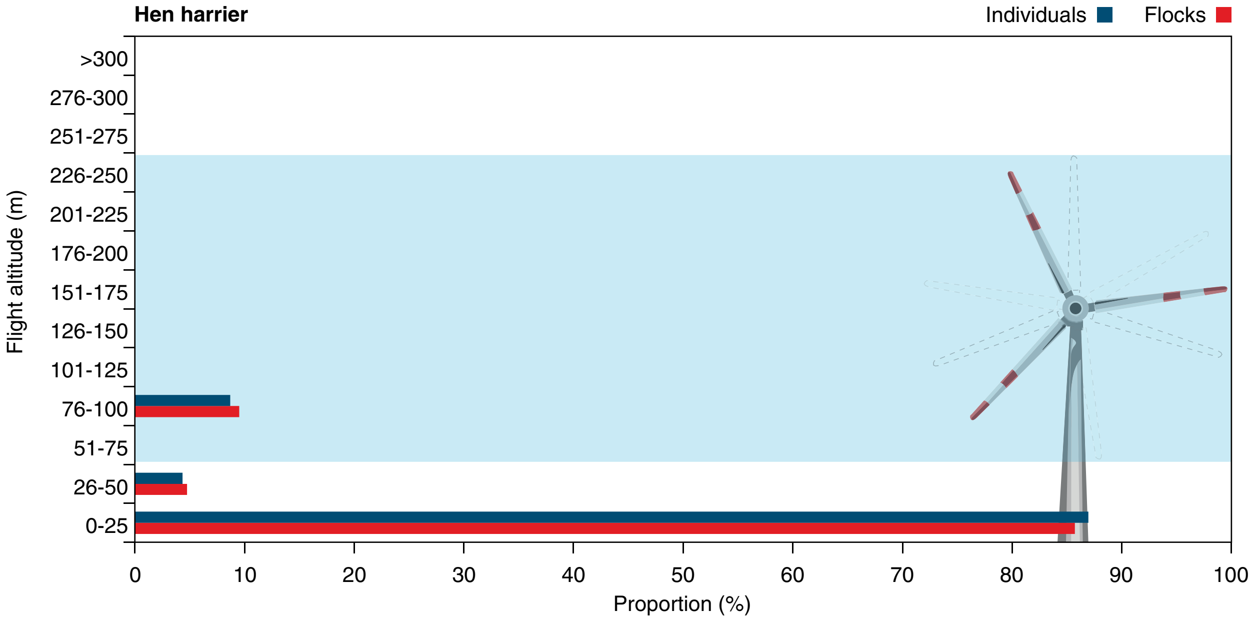


Figure 41. Flight altitudes of hen harriers expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.

Preliminary estimate of collision risk at turbines and other structures

The amount of collisions between hen harriers and wind turbines is negligible (0.005). However, it should be noted that although the study period covers most of the time during which hen harriers are present in the area, including October and November, where numbers peak throughout the country, no data were collected in early spring, where the peak spring migration takes place.

The preliminary estimate of the number of collisions, which is therefore based on a limited amount of data collected during one season, should therefore be interpreted with caution.

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. 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).

Preliminary assessment

Hen harrier is an extremely rare and irregular breeding bird in Denmark and therefore 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 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 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

Most buzzards were observed in the study area in September and October 2011 (Tab. 15), which may reflect an influx of southward migrating birds from N-Scandinavia. In autumn, on a few occasions, seasonal migration of flocks took place through the study area, although it should be noted that the spring observation period missed the peak migration, which takes place from late March until late April. Therefore little is known about the spring migration through the study area. However, since the test centre is situated off a migration corridor, we assume that most of the birds occurring in the study area are breeding, autumn staging or wintering individuals.

Buzzards were observed throughout the study area, although fewer observations were made in the southern parts (Fig. 42).This may reflect the fact that in a southerly direction the view and, hence, the probability of detecting low flying individuals and flocks were obstructed by trees. The minimum distances between flight paths of buzzards and future structures at the test centre are shown in Fig. 43.

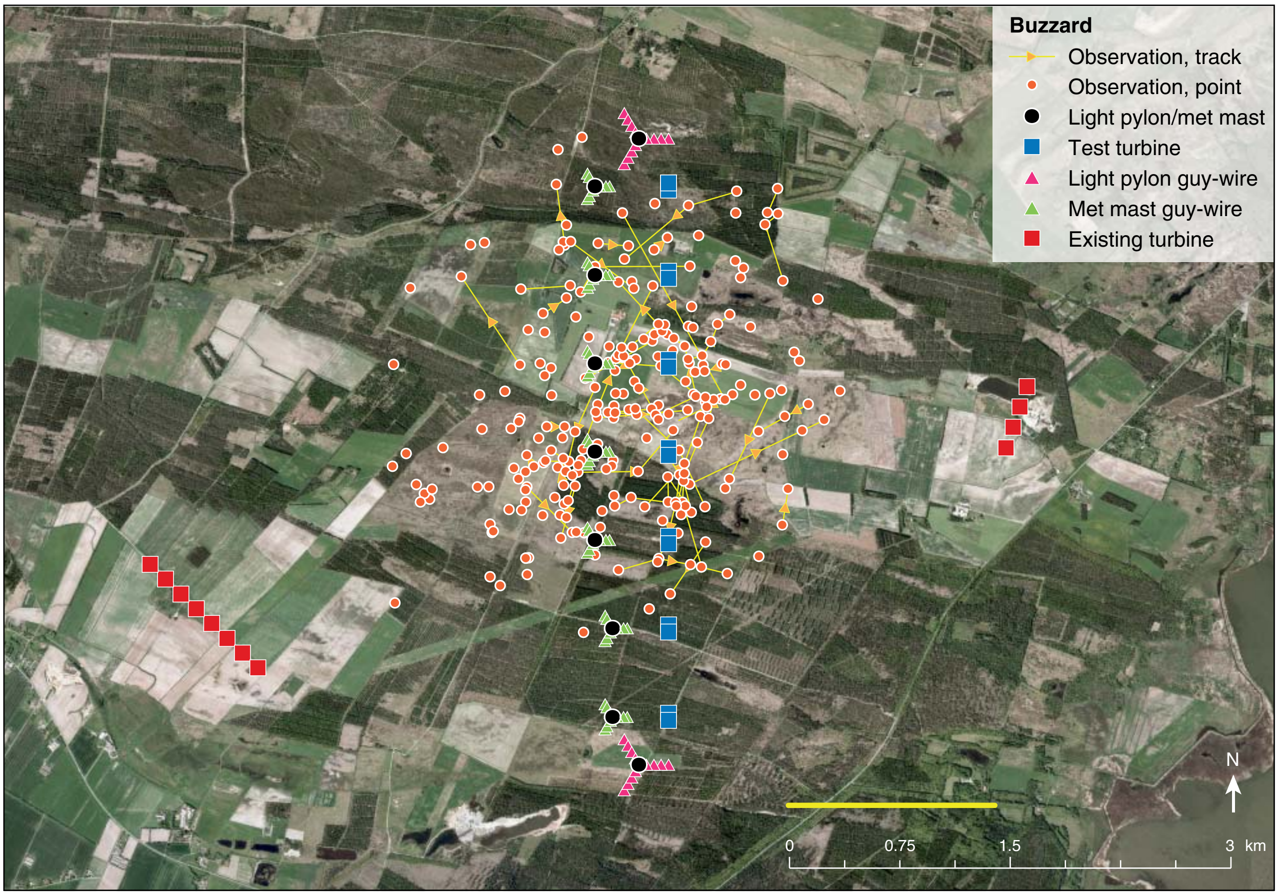


Figure 42. Overall flight patterns of buzzards in the study area, April-May 2011 and September 2011-February 2012. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Yellow arrows indicate the flight direction, and the yellow bar indicates the distance (1,402 m) from the observer within which 90% of the observation points were located.

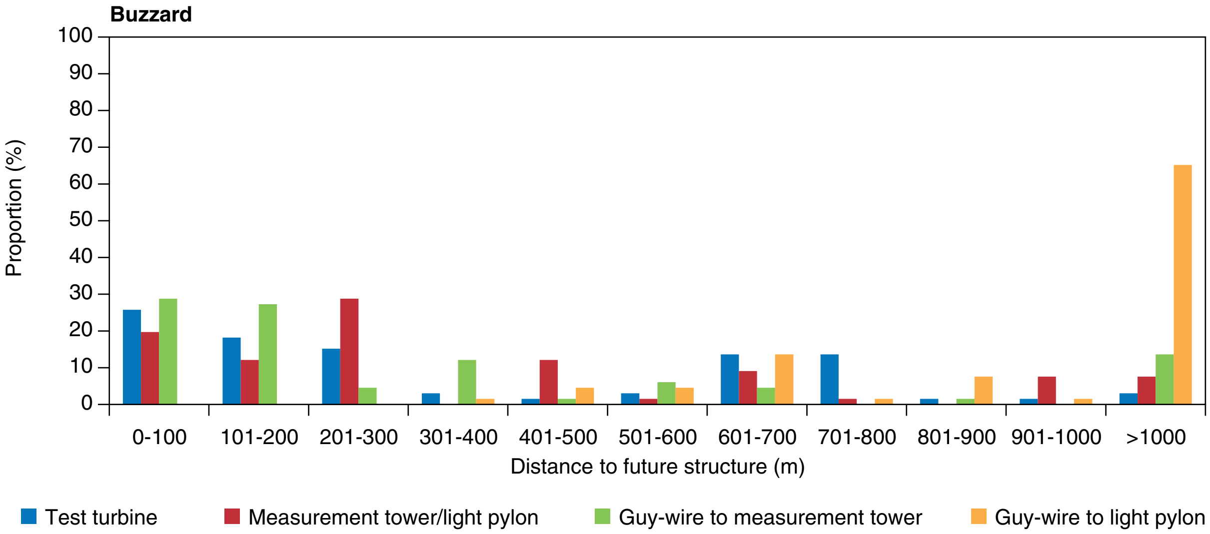


Figure 43. Distribution of minimum distances between flight paths of buzzards and future structures at the test centre, September 2011-February 2012. The proportion is weighted by the number of individuals in the observed flocks.

Staging individuals are highly mobile during the day, while they forage in open areas around the test centre. Most observations were made during midday, although the occurrence rate was not significantly different from evenings (Tab. 16). This was probably a result of a rise in daytime temperatures creating thermals used by soaring birds.

Table 16. Factors affecting the occurrence of buzzards in the study area (N=283 count periods).

Sub-model	Factor	Estimate	SE	Wald χ2	P
Normal. Numbers > 0	No factors significant				
Logistic	TIME morning	-1.8560	0.6725	7.62	0.0058
	TIME evening	-0.2140	0.4290	0.25	0.6178
	TIME mid-day	0			

Altogether, 36.8% and 40.6% of the observed individuals and flocks, respectively, of buzzards occurred at rotor height (50-250 m), whereas the remainder occurred below (Fig. 44). It should be noted that most observations were made during periods with favourable weather conditions, where flight height is expected to be higher than during periods with adverse weather conditions. (Tab. 17).

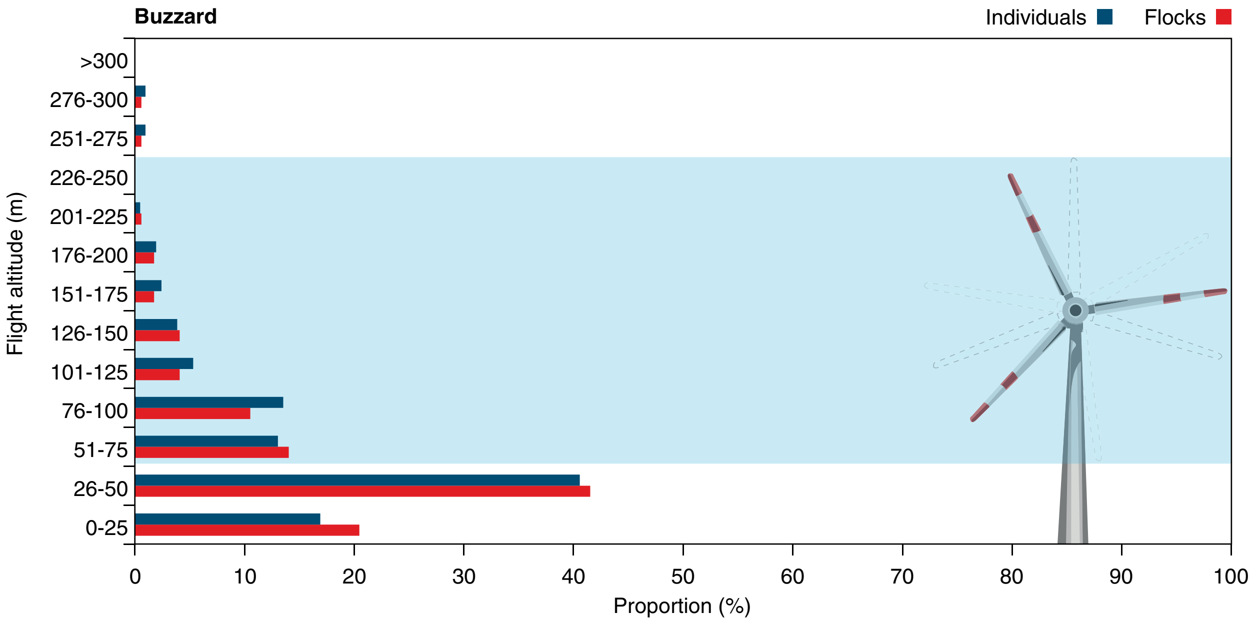


Figure 44. Flight altitudes of buzzards expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.

The flight altitude of flocks was higher than for individuals (Tab. 17), which probably reflect the fact that in most cases flocks represented migrating individuals using thermals to gain height, whereas foraging individuals tend to move between feeding areas at lower altitudes.

Table 17. Factors affecting the flight altitude of buzzards in the study are (N=145 flocks, r^2=0.12).

Factor	Estimate	SE	t	P
FLOCK	0,6062	0,1802	3,36	0,001
CLOUD	-0,0596	0,021	2,84	0,0051

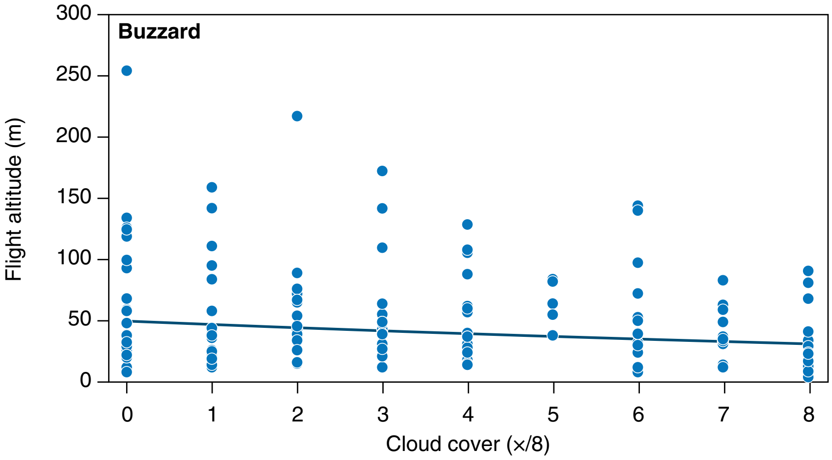


Figure 45. The relationship between cloud cover and flight altitude of buzzards (trendline: y=exp (3.9258-(0.0570*cloud))-1).

Flight altitude was negatively correlated with cloud cover (Fig. 45), which indirectly indicates that to some extent buzzards occurring in the study area used thermals to gain height. Therefore, during periods with favourable weather conditions, more individuals are expected to occur at rotor height.

Preliminary estimate of collision risk at turbines and other structures

Less than one (0.71) collision between buzzards and wind turbines is expected to take place in late spring and from September until the end of February. It should be noted that although the study period covers most of the time during which buzzards are present in the area, no data were collected in March and April 2012, when the peak spring migration of buzzards takes place.

It is important to notice that easterly winds may lead to higher migration intensity in West Jutland as birds of prey using thermals on their migration are displaced towards west in this situation. During such periods, more buzzards may pass through the study area, particularly in March.

The preliminary estimate of the number of collisions, which is based on a relatively limited amount of data collected during one season, should therefore be interpreted with caution.

Preliminary 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 considered to be insignificant.

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

Peregrine falcons were observed in September and October near the observation in the central part of the study area (Tab. 18, Fig. 46).

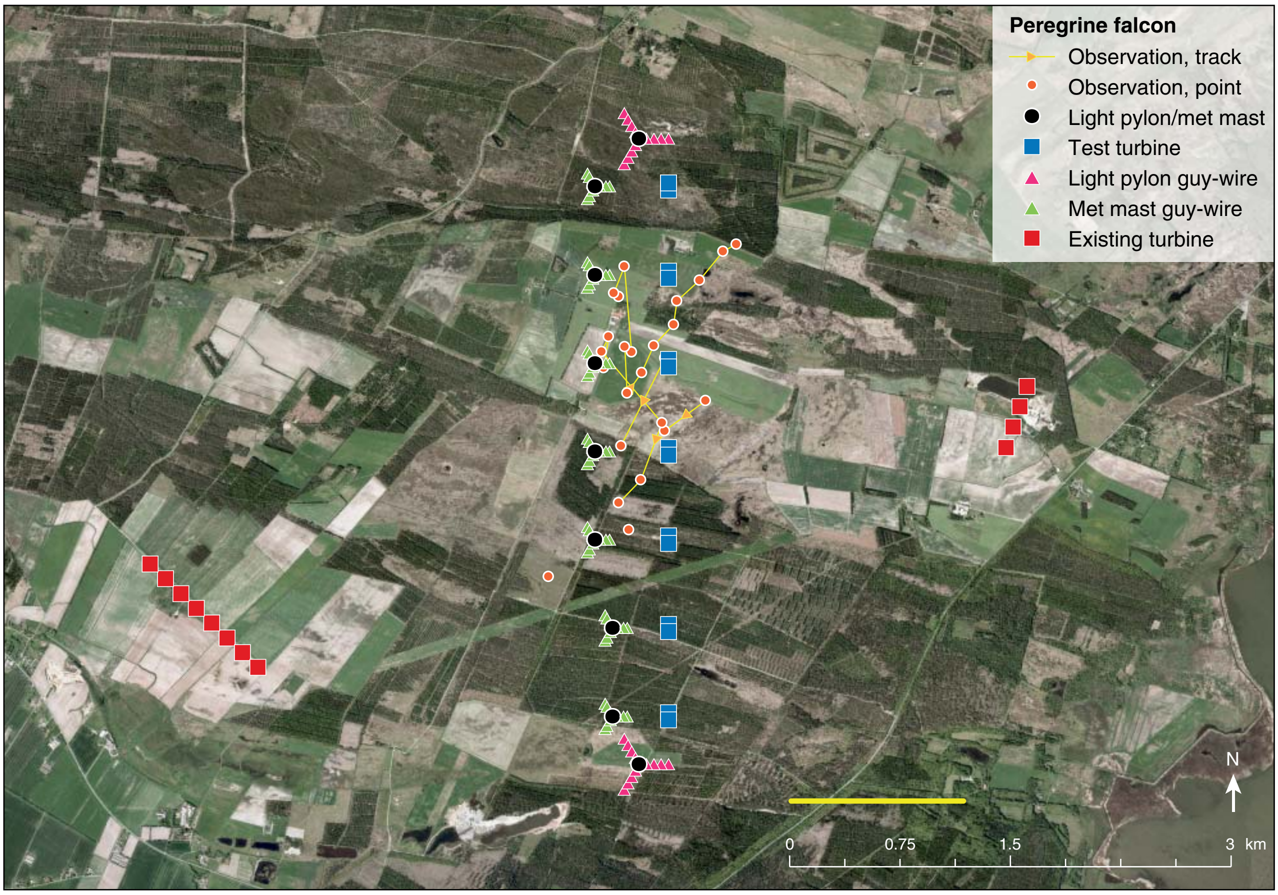


Figure 46. Overall flight patterns of peregrine falcons in the study area, April-May 2011 and September 2011-February 2012. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Yellow arrows indicate the flight direction, and the yellow bar indicates the distance (1,171 m) from the observer within which 90% of the observation points were located.

The few peregrine falcons observed in the study area, were probably autumn staging individuals of unknown origin.

Altogether, 33.3% of the observed individuals of peregrine falcons occurred at rotor height (50-250 m), whereas 66.6% were found below rotor height (Fig. 47). On some occasions peregrine falcons undertook aerial pursuit of barn swallows in the wind farm area.

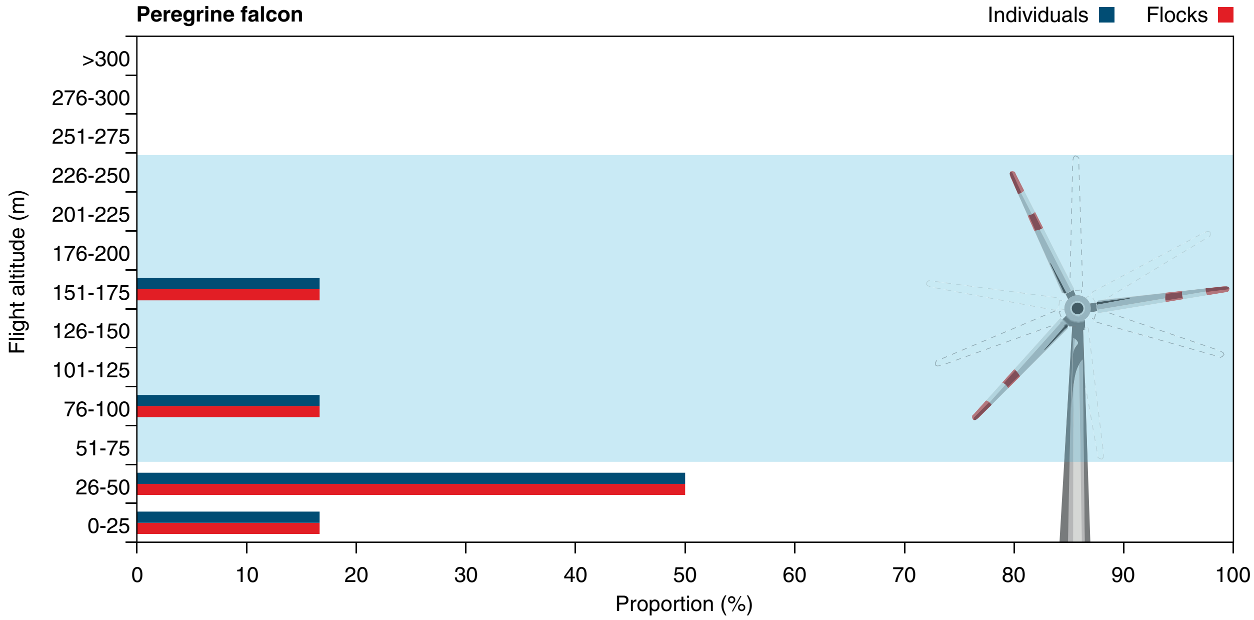


Figure 47. Flight altitudes of peregrine falcons expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.

Preliminary estimate of collision risk at turbines and other structures

Less than one (0.01) collision between peregrine falcons and wind turbines is expected to take place in late spring and from September until the end of February. Likewise, under most circumstances, the risk of collisions between peregrine falcons and other structures at the test centre is expected to be of minor importance, although low visibility may increase the risk of collisions. It should be noted that although the period covers most of the time during which peregrine falcons are present in the area, including September and October, where numbers peak throughout the country, no data were collected in early spring, where the peak spring migration of peregrine falcons takes place. However, the small number of observations also indicates that the study area is only used occasionally by peregrine falcons. The preliminary estimate of the number of collisions, which is therefore based on a very limited amount of data collected during one season, should therefore be interpreted with caution.

Preliminary assessment

The Danish breeding population is small (around 10 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 scarce occurrence of staging or overwintering individuals in the study area, we consider the potential negative effects on peregrine falcons to be negligible.

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 (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 the breeding population in Northwest Jutland. In recent years, a pair of common cranes has been breeding in the northern part of the study area (H.H. Nielsen, pers. comm.)

Temporal and spatial patterns of occurrence in the study area

Common crane was observed in the study area in late spring 2011, September and October 2011 and late winter 2012 (Tab. 19). No data were collected during the peak migration period, which occurs in late March. However, migrating common cranes mainly pass through Denmark in the eastern part of the country, although prevailing winds from an easterly direction may force migrants further west. Nevertheless, we assume that most of the individuals observed during the study periods comprise breeders and individuals that have not reached the age of maturity (4 years).

Table 19. Numbers of common cranes passing the wind farm area on visual transects in late spring (April 29-May 26 2011) and September 2011-February 2012 expressed as observed/calculated number of individuals.

	Late spring	Sep	Oct	Nov	Dec	Jan	Feb
North		0/0	0/0	0/0	0/0	2/81	2/74
South		31/733	6/198	0/0	0/0	0/0	0/0
Total	35/391	31/733	6/198	0/0	0/0	2/81	2/74

Most of the common cranes were tracked near the observation station in the central part of the study area. The majority of flocks moved in an east-westerly direction (Fig. 48), which supports the 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. The minimum distances between flight paths of common cranes and future structures at the test centre are shown in Fig. 49.

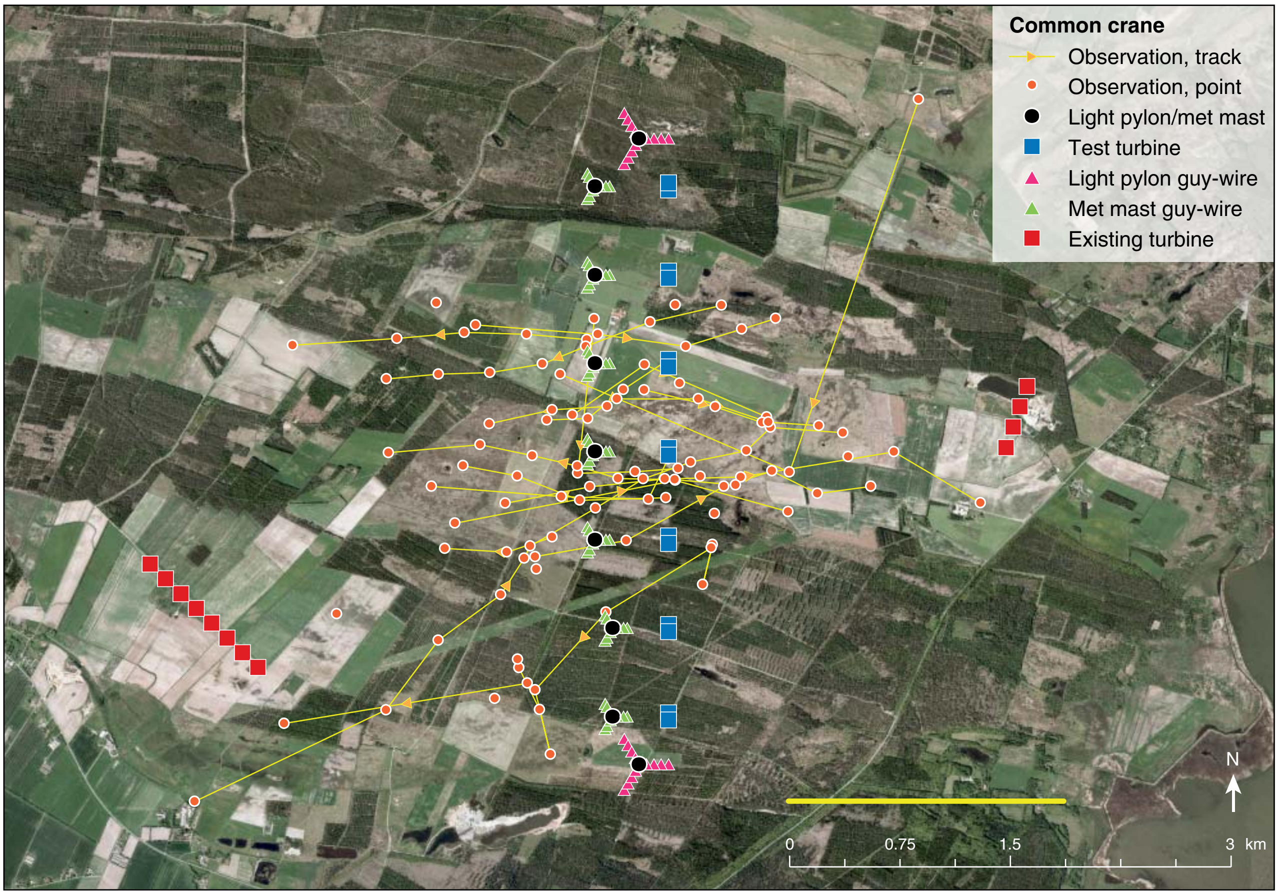


Figure 48. Overall flight patterns of common crane in the study area, April-May 2011 and September 2011-February 2012. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Yellow arrows indicate the flight direction, and the yellow bar indicates the distance (1,869 m) from the observer within which 90% of the observation points were located.

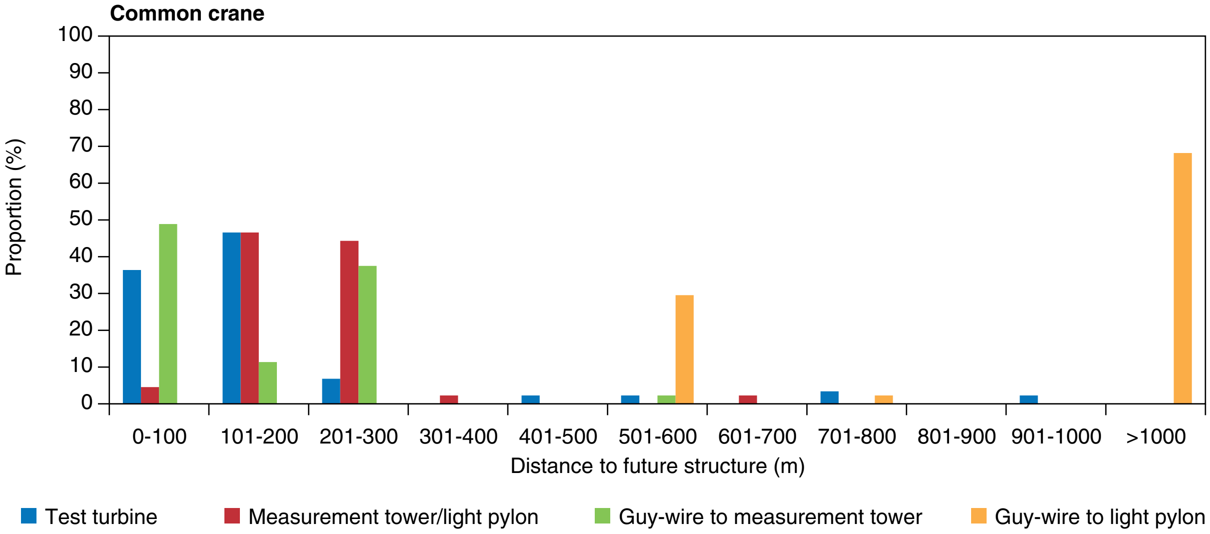


Figure 49. Distribution of minimum distances between flight paths of common cranes and future structures at the test centre, September 2011-February 2012. The proportion is weighted by the number of individuals in the observed flocks.

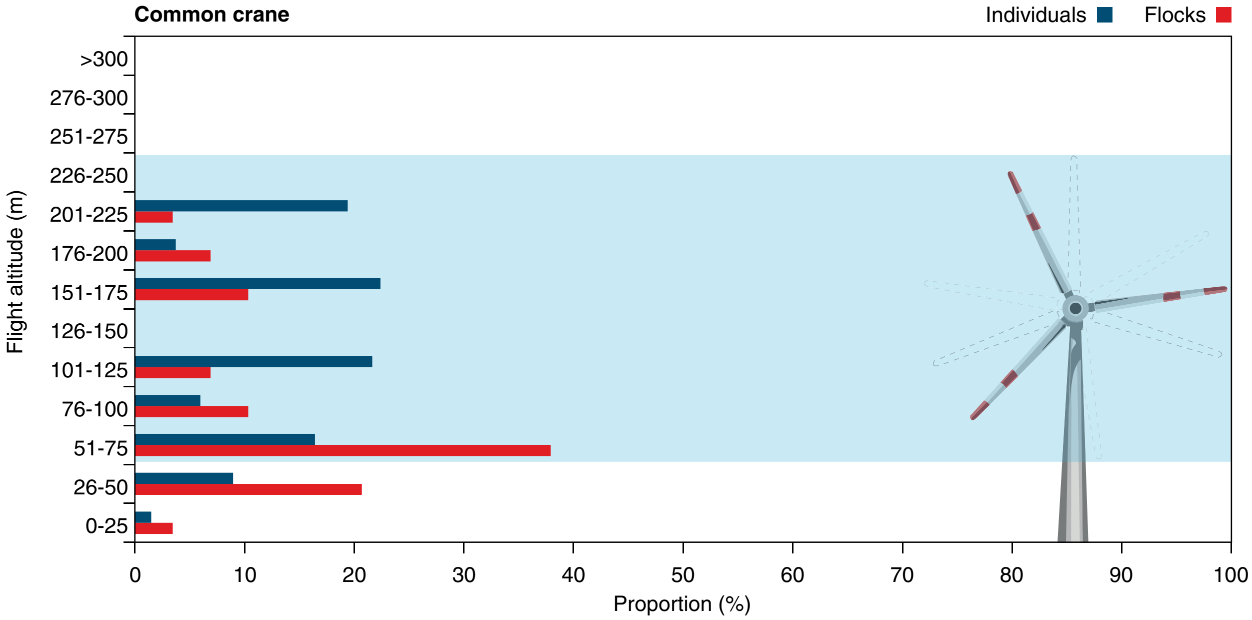


Figure 50. Flight altitudes of common cranes expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.

Altogether, 75.9% and 89.6% of the observed individuals and flocks, respectively, of common cranes occurred at rotor height (50-250 m), whereas the remainder were below rotor height (Fig. 50).

Preliminary estimate of collision risk at turbines and other structures

Less than one (0.37) collision between common cranes wind turbines is expected to take place in late spring and from September until the end of February. At nearby Klim Fjordholme Kahlert & Therkildsen (2012) found that common cranes tended to be more active around and before dawn. This observation combined with 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 associated risk of collisions between this species and other structures at the test centre, e.g. guy wires and towers. This is particularly the case in situations, where visibility is reduced due to adverse weather conditions.

It should be noted that although the study period covers most of the time during which common cranes are present in the area, no data were collected from in March and April 2012, where the peak spring migration and the arrival to the breeding grounds takes place. Likewise, no data were collected during summer and therefore the extent to which local breeding pairs may use the study areas during this period remains unknown. The preliminary estimate of the number of collisions, which is based on a relatively limited amount of data collected during one season, should be interpreted with great caution.

Preliminary assessment

Common crane is a scarce breeding bird in Denmark, although the population has increased in recent years. The relatively small size of the populations means that in the case of a collision between a breeding bird and a turbine or tower, a relatively large proportion of the Danish and the regional population would be affected. Therefore, common crane will be included in the post-construction programme as a focal species to obtain more data, particularly from critical periods of the annual cycle. This will improve the level of detail in the assessment of potential negative effects 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 in late spring and again from September until December. Highest numbers were registered in October, although it should be noted that one single observation at this time accounted for 96% of the total number of individuals registered on visual transects during the study period (Tab. 20).

Table 20. Numbers of golden plovers passing the wind farm area on visual transects in late spring (April 29-May 26 2011) and September 2011-February 2012 expressed as observed/calculated number of individuals.

	Late spring	Sep	Oct	Nov	Dec	Jan	Feb
North		108/2098	2/55	61/1982	40/1360	0/0	0/0
South		91/2153	8004/263512	4/156	0/0	0/0	0/0
Total	115/6416	199/4251	8006/263566	65/2138	40/1360	0/0	0/0

Golden plovers were mainly observed near the central observation station (Fig. 51). The minimum distances between flight paths of golden plovers and future structures at the test centre are shown in Fig. 52.

Altogether, 82.1% and 96.3% of the observed individuals and flocks, respectively, of golden plovers occurred at rotor height (50-250 m), whereas the remainder were below rotor height (Fig. 53).

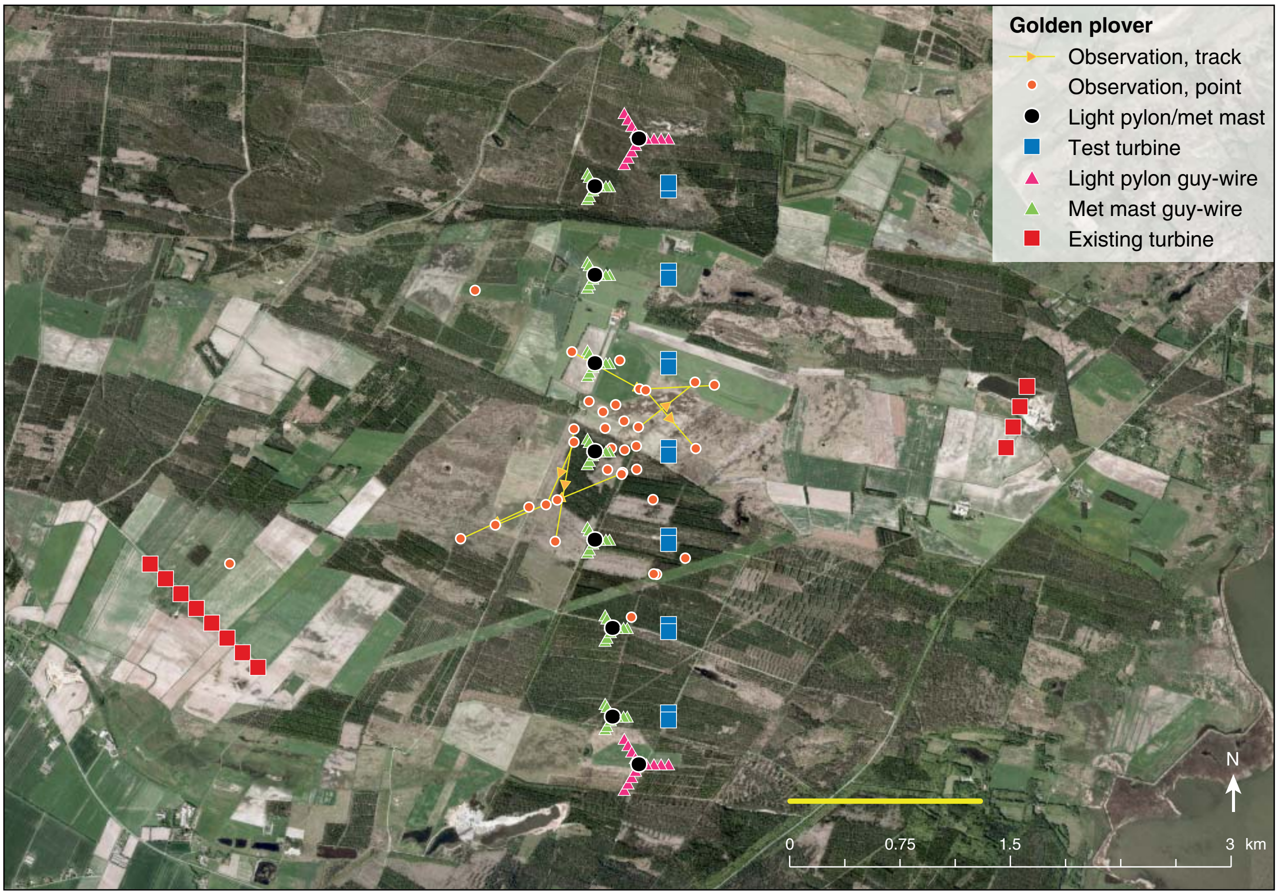


Figure 51. Overall flight patterns of golden plovers in the study area, April-May 2011 and September 2011-February 2012. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Yellow arrows indicate the flight direction, and the yellow bar indicates the distance (1,294 m) from the observer within which 90% of the observation points were located.

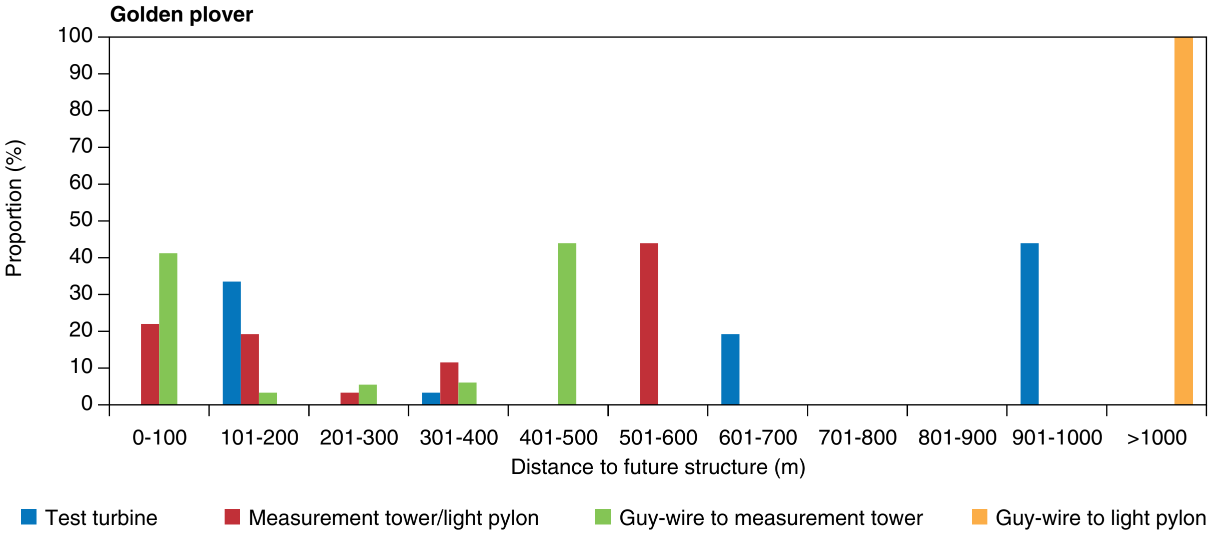


Figure 52. Distribution of minimum distances between flight paths of golden plovers and future structures at the test centre, late spring 2011 and September 2011-February 2012. The proportion is weighted by the number of individuals in the observed flocks.

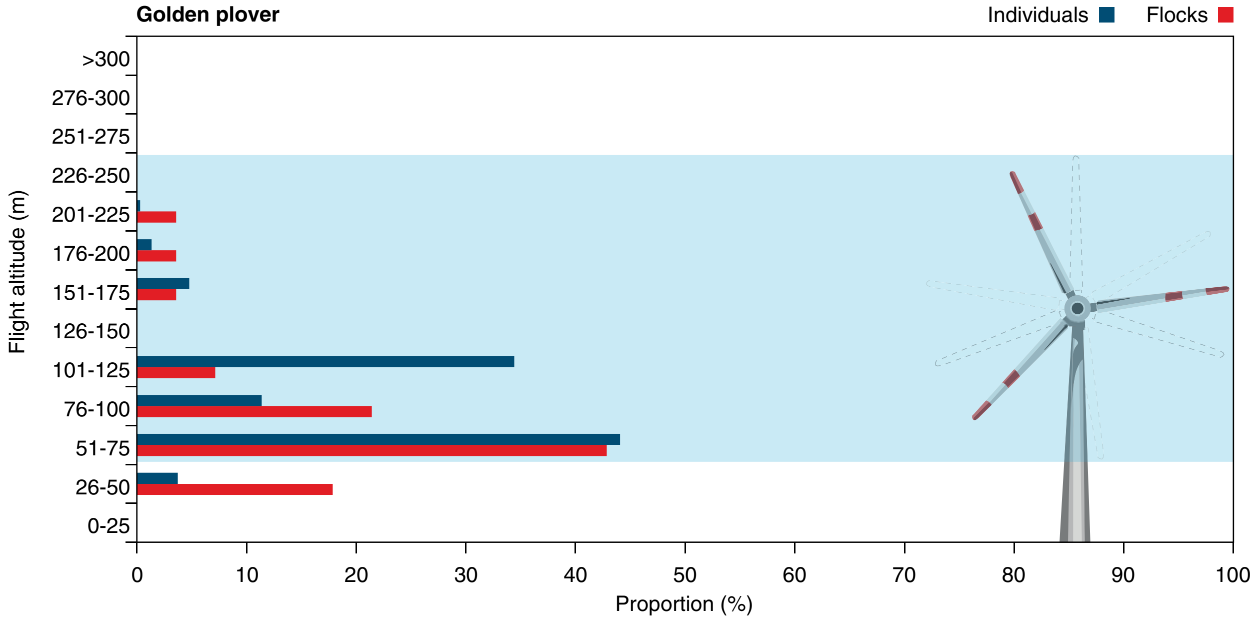


Figure 53. Flight altitudes of golden plovers expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.

Preliminary estimate of collision risk at turbines and other structures

A total of 65 collisions between golden plovers and wind turbines are expected to take place in late spring and from September to the end of February. It should be noted that although the period covers most of the annual cycle, no data were collected in March, April and August, when golden plovers also occur in the country in significant numbers. The preliminary estimate of the number of collisions, which is based on a relatively limited amount of data collected during one season, should therefore be interpreted with caution.

We therefore 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 associated risk of collisions between this species and other structures at the test centre, e.g. guy wires and towers. During the day, this may also be the case in situations, where visibility is reduced due to adverse weather conditions.

Preliminary assessment

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 considered to be insignificant. However, it should be noted that on the basis of the regular occurrence of staging and wintering individuals in Northwest Jutland, data will 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 species.

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, November and February, which to some extent coincided with the peak migration periods of this species (Tab. 21).

Table 21. Numbers of wood pigeons passing the wind farm area on visual transects in late spring (April 29-May 26 2011) and September 2011-February 2012 expressed as observed/calculated number of individuals.

	Late spring	Sep	Oct	Nov	Dec	Jan	Feb
North		62/1446	19/626	16/624	12/490	22/895	46/1703
South		25/591	51/1679	0/0	10/408	19/804	9/344
Total	18/1004	87/2038	70/2305	16/624	22/898	41/1700	55/2047

Most wood pigeons were observed close to the central observation station. This pattern probably reflects the low flight altitude of wood pigeons making it difficult to detect individuals and flocks at larger distances, where the view may be obstructed by trees. Therefore more individuals may have occurred in other parts of the study area (Fig. 54). The minimum distances between flight paths of wood pigeons and future structures at the test centre are shown in Fig. 55.

Lowest occurrence rate of wood pigeons was registered during periods with southwesterly winds and there was a positive correlation between occurrence of wood pigeons and temperature (Tab. 22). The latter was probably a result of an influx of Northern Scandinavian birds in early autumn.

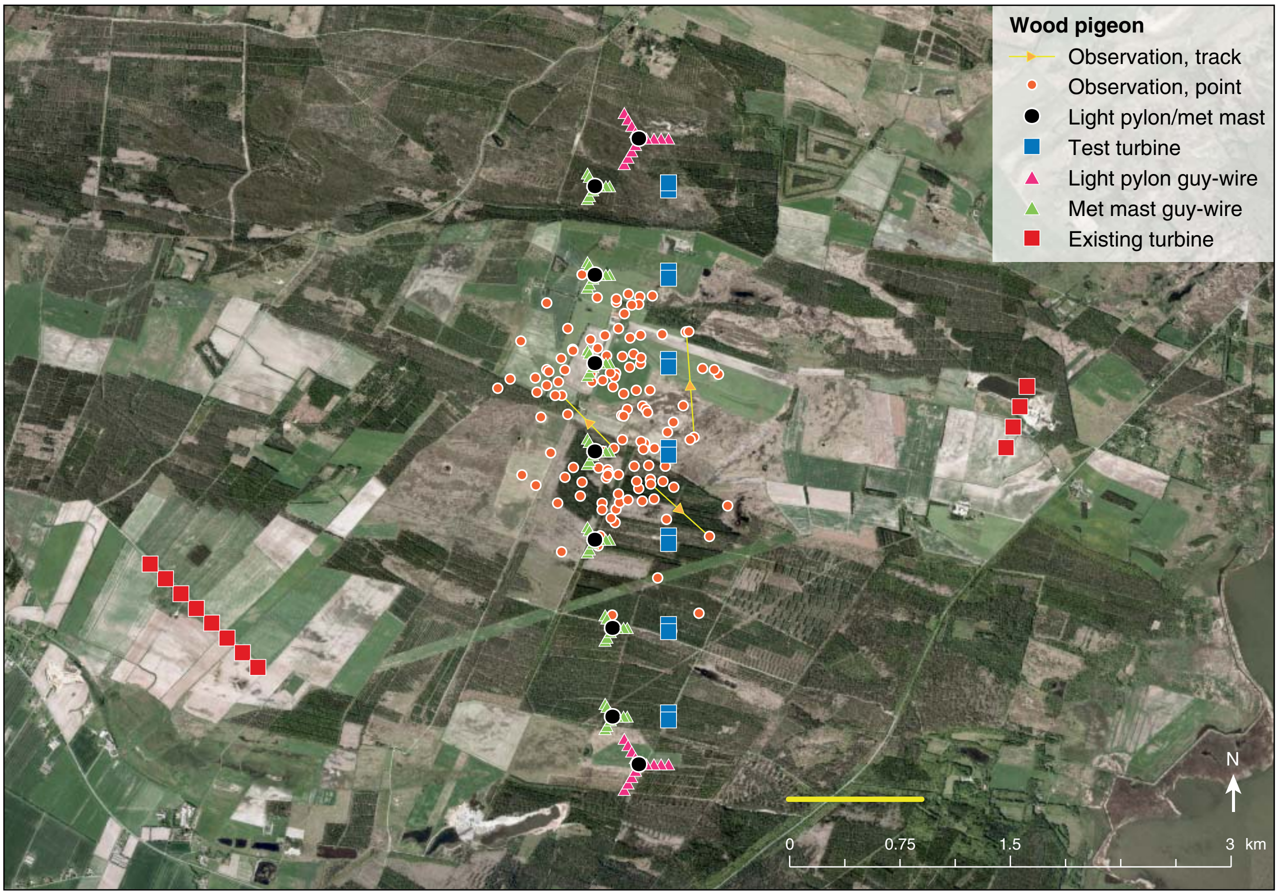


Figure 54. Overall flight patterns of wood pigeons in the study area, April-May 2011 and September 2011-February 2012. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Yellow arrows indicate the flight direction, and the yellow bar indicates the distance (904 m) from the observer within which 90% of the observation points were located.

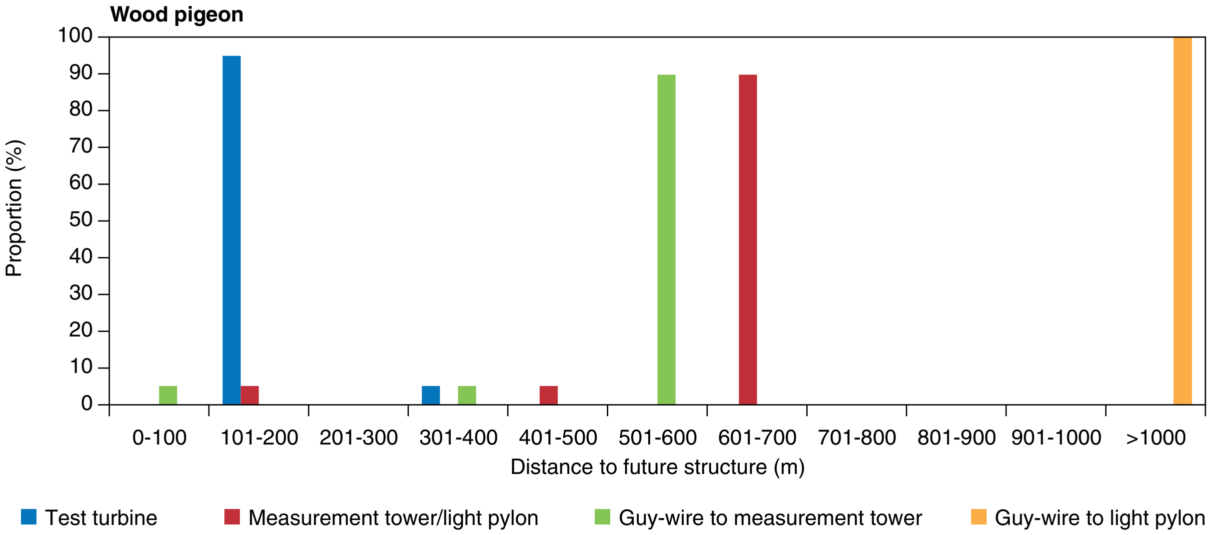


Figure 55. Distribution of minimum distances between flight paths of wood pigeons and future structures at the test centre, September 2011-February 2012. The proportion is weighted by the number of individuals in the observed flocks.

Table 22. Factors affecting the occurrence of wood pigeons in the study area (N=391 count periods).

Sub-model	Factor	Estimate	SE	Wald χ2	P
Normal. Numbers > 0	No factors significant				
Logistic	WINDDIR NE	1.9511	0.7484	6.8	0.0091
	WINDDIR NW	0.7651	0.338	5.12	0.0236
	WINDDIR SE	0.5873	0.4413	7.37	0.1832
	WINDDIR SW				
	TEMP	0.0729	0.0269	7.37	0.0066

Altogether, 18.6% and 27.8% of the observed individuals and flocks, respectively, of wood pigeons occurred at rotor height (50-250 m), whereas the remainder were below rotor height (Fig. 56).

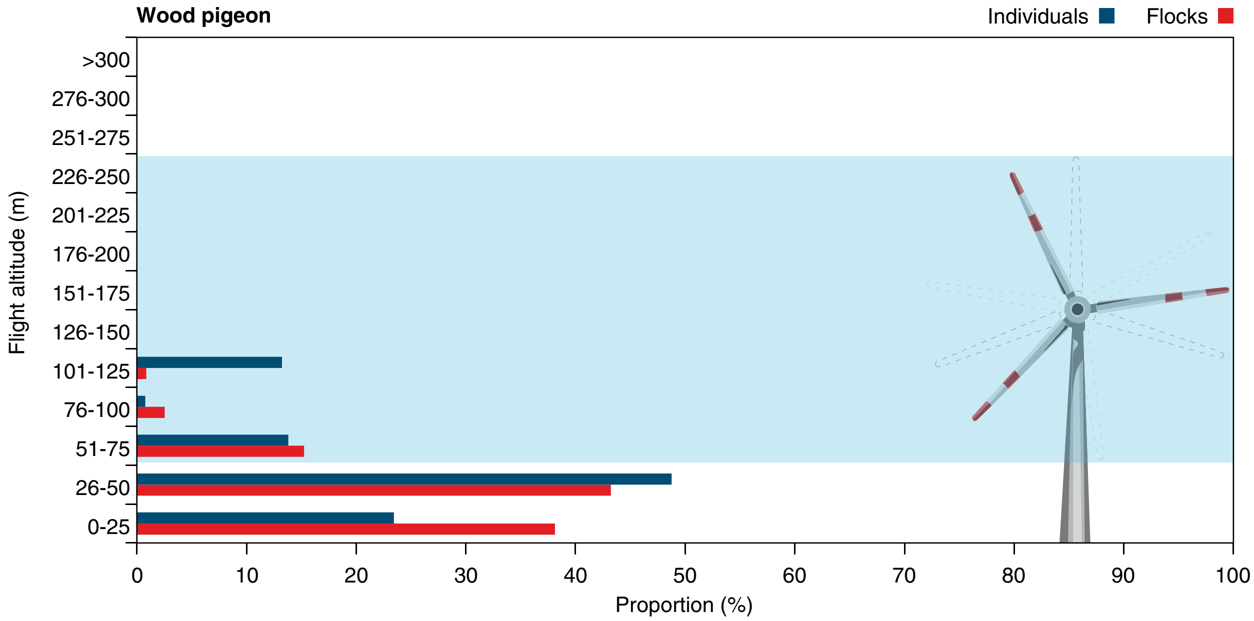


Figure 56. Flight altitudes of wood pigeons expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.

Preliminary estimate of collision risk at turbines and other structures

Less than one collision (0.91) between wood pigeons and wind turbines is expected to take place in late spring and from September until the end of February. It should be noted that although the period covers most of the annual cycle, no data were collected in March and April, when some migrants may still occur, and during most of the breeding season.

The preliminary estimate of the number of collisions, which is based on a relatively limited amount of data collected during one season, should therefore be interpreted with some caution.

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 local birds. This is supported by the relatively low flight altitude observed among wood pigeons.

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

Preliminary assessment

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 considered to be negligible.

Great grey shrike

General occurrence

Great grey shrike is a rare breeding bird in Denmark (<10 pairs) and most of the individuals observed in the country are migrants originating from Northern Scandinavia. Numbers in Denmark peak during spring (March-April) and autumn migration (October). During winter, great grey shrike occurs throughout the country, although in small numbers (350-450 individuals).

Temporal and spatial patterns of occurrence in the study area

In total, five great grey shrikes were observed on transects in October, November and January. Observations were all in the central part of the study area (Fig. 57). To some extent this may reflect difficulties detecting low-flying individuals at longer distances and that the view was obstructed by trees in some directions. Therefore more individuals may have occurred in other parts of the study area. It should also be noted that probably the same individual was registered more than once during the study period.

All the great grey shrikes observed in the study area occurred below rotor height (50-250 m) (Fig. 58).

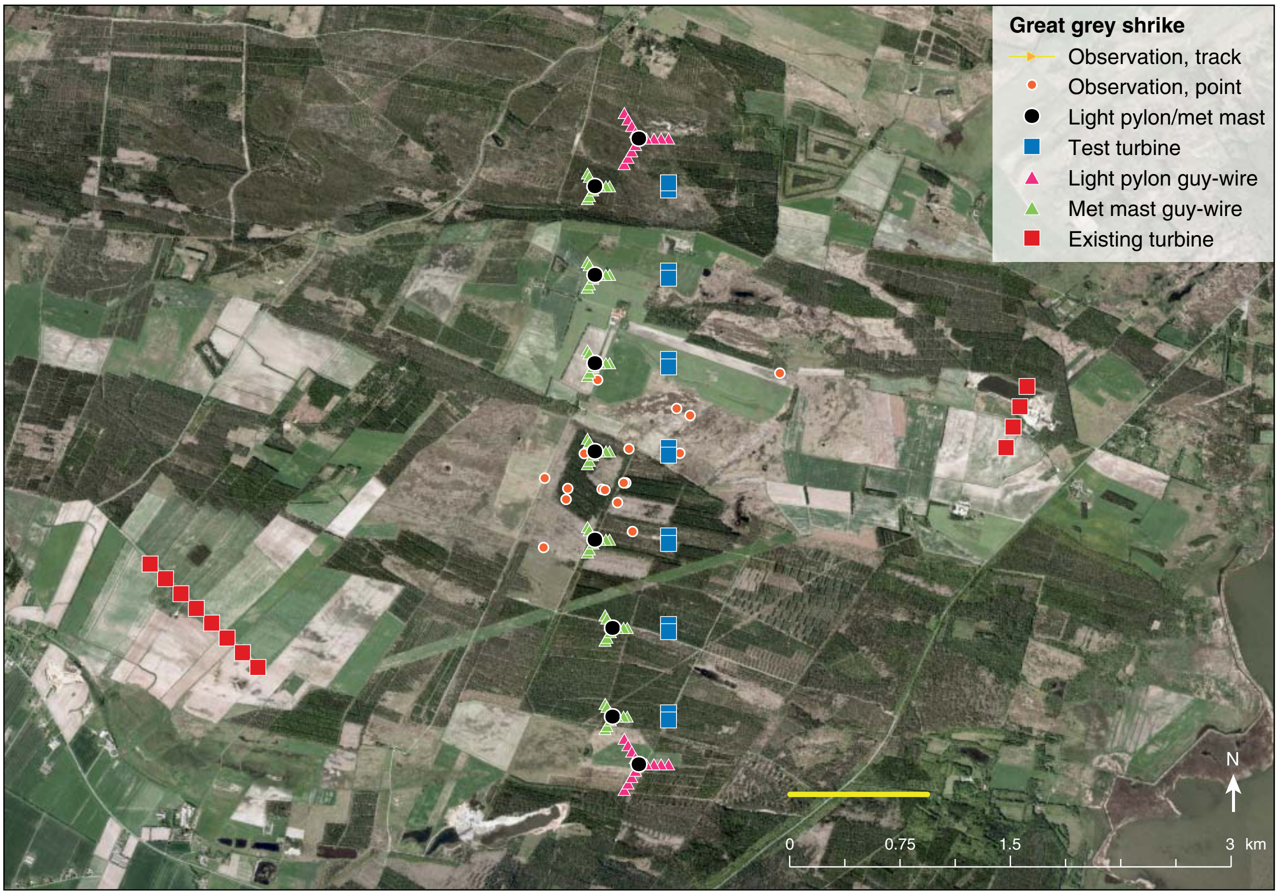


Figure 57. Occurrences of great grey shrikes in the study area, April-May 2011 and September 2011-February 2012. Red dots indicate observation points obtained by laser range finder. The yellow bar indicates the distance (935 m) from the observer within which 90% of the observation points were located.

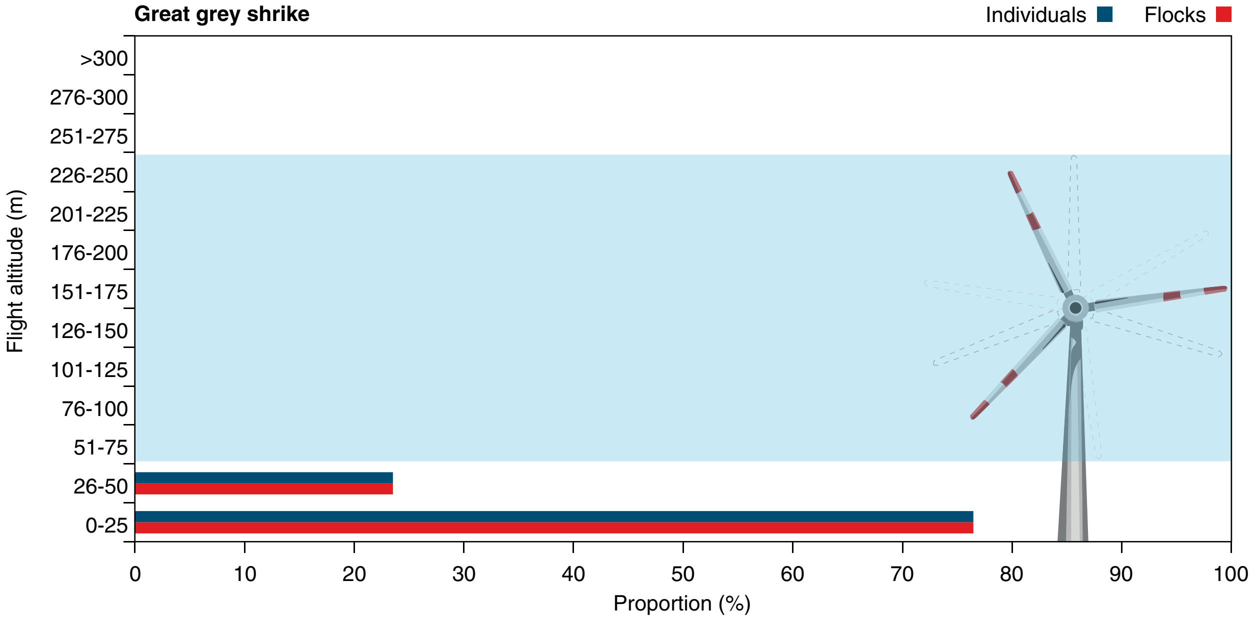


Figure 58. Flight altitudes of great grey shrikes expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.

Preliminary estimate of collision risk at turbines and other structures

Predictions of the collision risk at the planned test turbines were not estimated for great grey shrike as it may have been overlooked on the transect counts. However, the risk of collisions between great grey shrikes and wind turbines and other structures is assessed to be negligible. This is mainly due to the small numbers observed combined with the low flight altitude of great grey shrikes. However, it should be noted that although the period covers most of the time during which great grey shrikes are present in the area, including October and November, where numbers peak throughout the country, no data were collected in early spring, where the peak spring migration takes place.

Preliminary assessment

Great grey shrike is a rare breeding bird in Denmark and therefore 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 the study area. However, considering the absence of breeding pairs in North Jutland, the relatively limited occurrence of staging or overwintering individuals in the study area, and the occurrence below rotor height, we consider the potential negative effects on this species to be negligible.

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 was registered in small numbers in September-October (Tab. 23).

Table 23. Numbers of common ravens passing the wind farm area on visual transects in late spring (April 29-May 26 2011) and September 2011-February 2012 expressed as observed/calculated number of individuals.

	Late spring	Sep	Oct	Nov	Dec	Jan	Feb
North		4/93	4/132	0/0	0/0	0/0	0/0
South		4/95	2/66	0/0	0/0	0/0	0/0
Total	0/0	8/188	6/198	0/0	0/0	0/0	0/0

Most common ravens were observed close to the central observation station. This pattern probably reflects that in most cases flight altitude of common ravens was low making it difficult to detect individuals at larger distances, where the view may be obstructed by trees. Therefore more individuals may have occurred in other parts of the study area (Fig. 59). The minimum distances between flight paths of common ravens and future structures at the test centre are shown in Fig. 60.

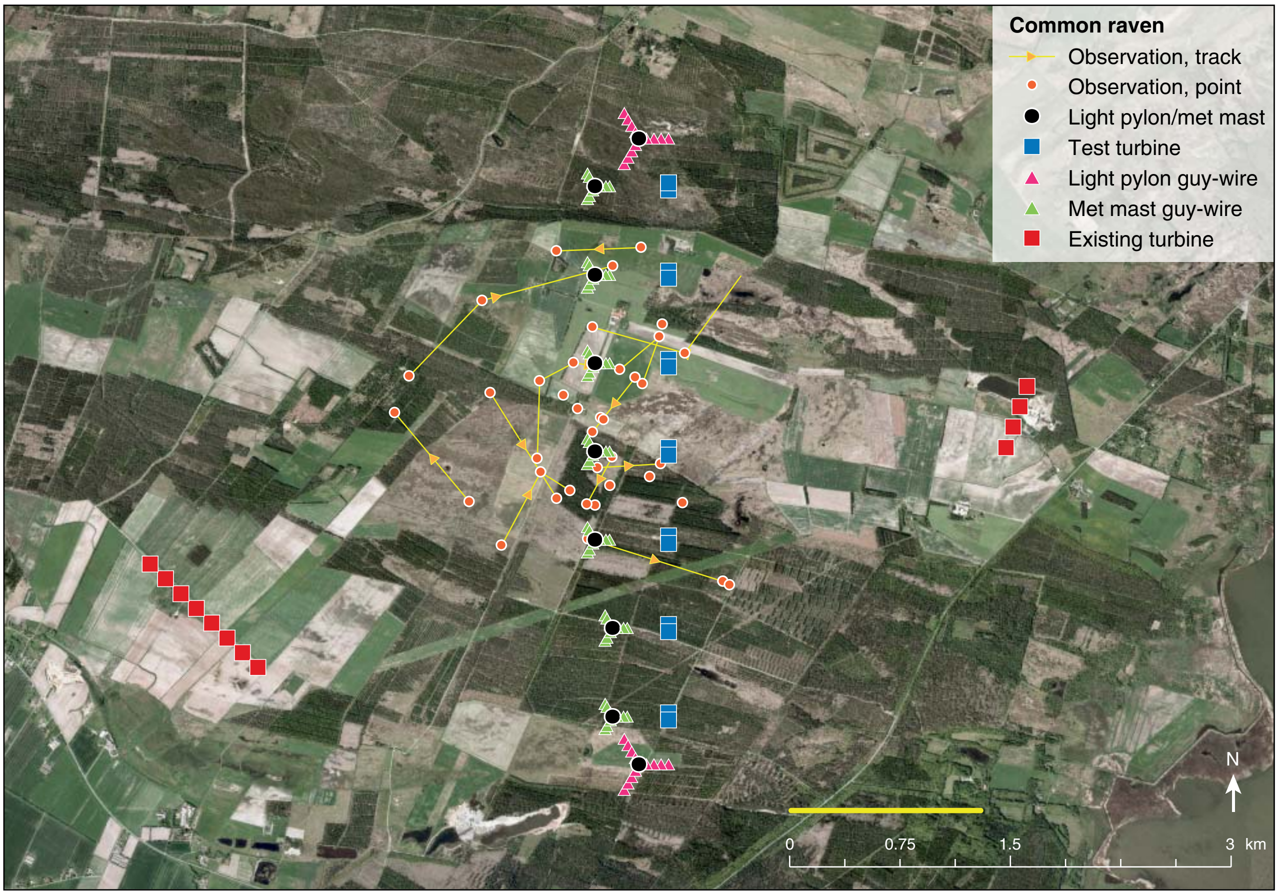


Figure 59. Overall flight patterns of common ravens in the study area, April-May 2011 and September 2011-February 2012. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Yellow arrows indicate the flight direction, and the yellow bar indicates the distance (1,289 m) from the observer within which 90% of the observation points were located.

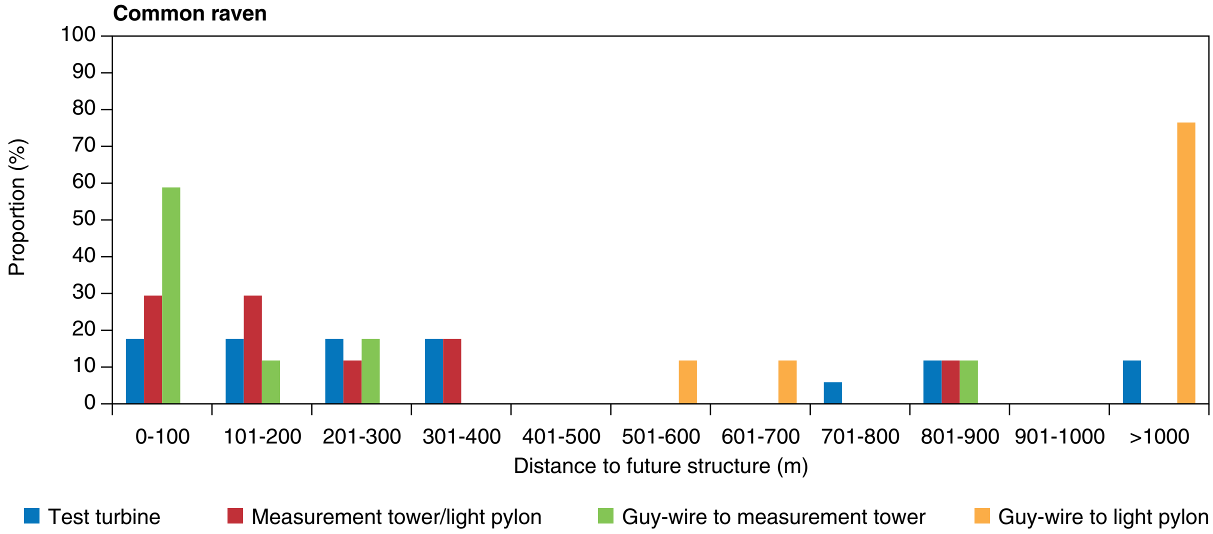


Figure 60. Distribution of minimum distances between flight paths of common ravens and future structures at the test centre, September 2011-February 2012. The proportion is weighted by the number of individuals in the observed flocks.

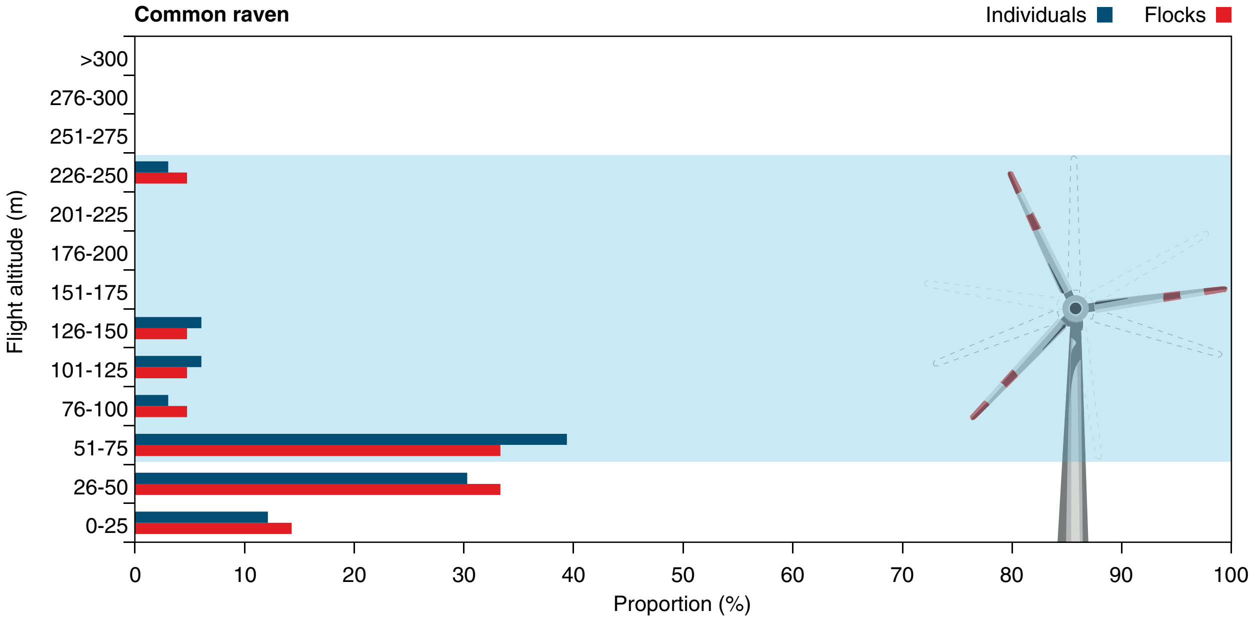


Figure 61. Flight altitudes of common ravens expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.

Altogether, 52.4% and 57.6% of the observed individuals and flocks, respectively, of common ravens occurred at rotor height (50-250 m), whereas the remainder were below rotor height (Fig. 61).

Preliminary estimate of collision risk at turbines and other structures

Less than one collision (0.08) between common ravens and wind turbines is expected to take place in late spring and from September until the end of February. It should be noted that although the period covers most of the annual cycle, no data were collected during the breeding season.

The preliminary estimate of the number of collisions, which is based on a relatively limited amount of data collected during one season, should therefore be interpreted with great caution.

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.

There may be an associated risk of collisions between common ravens and other structures at the test centre, e.g. guy wires and towers. 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.

Preliminary 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 consider the potential negative effect on common raven in the study area to be negligible.

Passerines, daytime

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 N-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, wagtails and pipits) and nocturnal migrants (e.g. thrushes, warblers and flycatchers). However, this strict separation is weakened by 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.

Temporal and spatial patterns of occurrence in the study area

Passerines occurred in the study area throughout the study period (Tab. 24). Numbers peaked in October and November, which probably reflects an influx of Northern Scandinavian birds at this time.

Table 24. Numbers of passerines passing the wind farm area on visual transects in late spring (April 29-May 26 2011) and September 2011-February 2012 expressed as observed/calculated number of individuals.

	Late spring	Sep	Oct	Nov	Dec	Jan	Feb
North		307/7160	860/28313	1063/41457	126/5143	148/6023	270/9997
South		65/1538	182/5992	179/6981	183/7469	137/5799	299/11417
Total	99/5524	372/8698	1042/34305	1242/48438	309/12612	285/11822	569/21414

For the smaller species such as swallows, wagtails, finches and thrushes, detection is difficult at distances beyond 600 m, unless birds occur in dense flocks. Therefore passerines were mainly observed near the observation stations and only few flight patterns were obtained (Fig. 62). The minimum distances between passerines and future structures at the test centre are shown in Fig. 63.

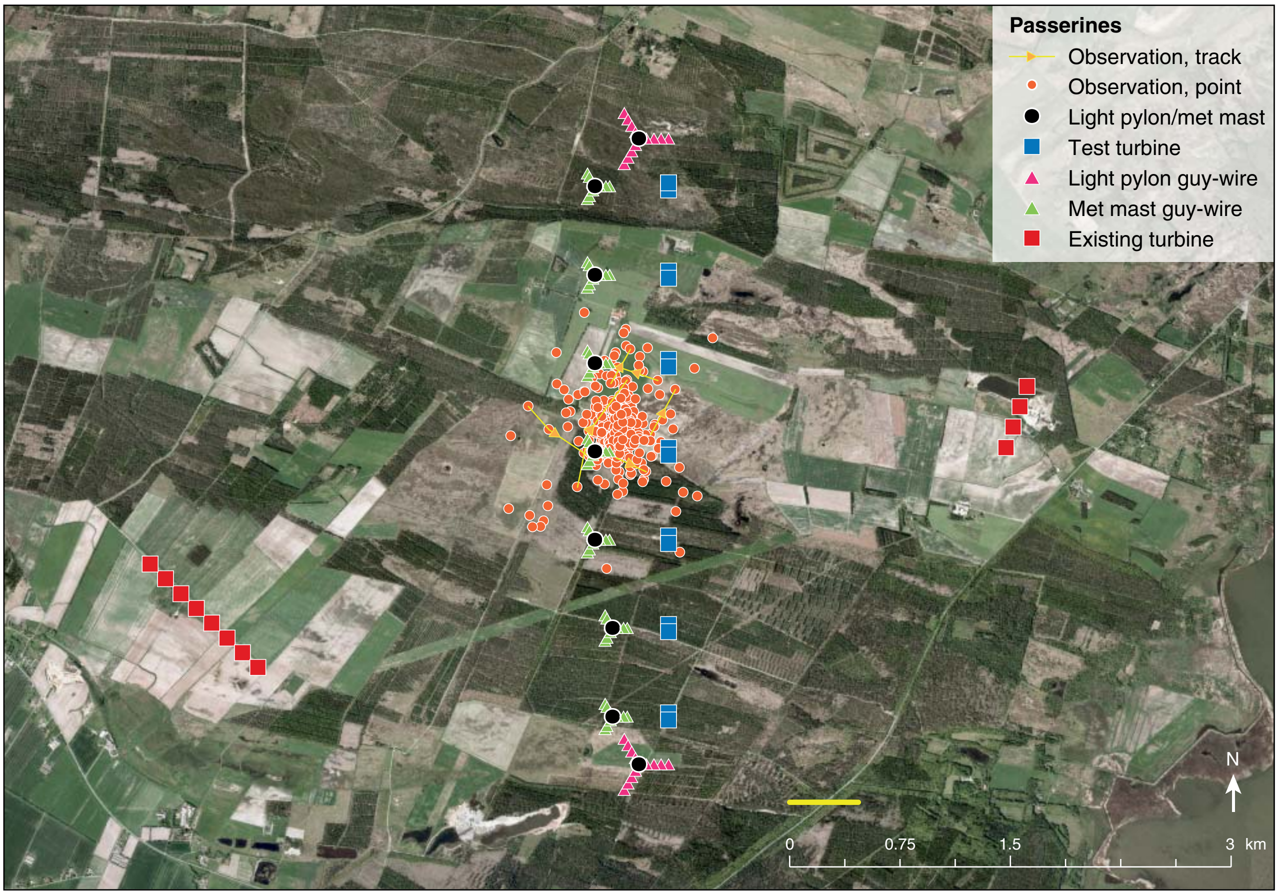


Figure 62. Observations of passerines in the study area, April-May 2011 and September 2011-February 2012. Red dots indicate observation points obtained by laser range finder. Sequential observations of the same flock or individual are connected with a yellow line. Yellow arrows indicate the flight direction, and the yellow bar indicates the distance (466 m) from the observer within which 90% of the observation points were located.

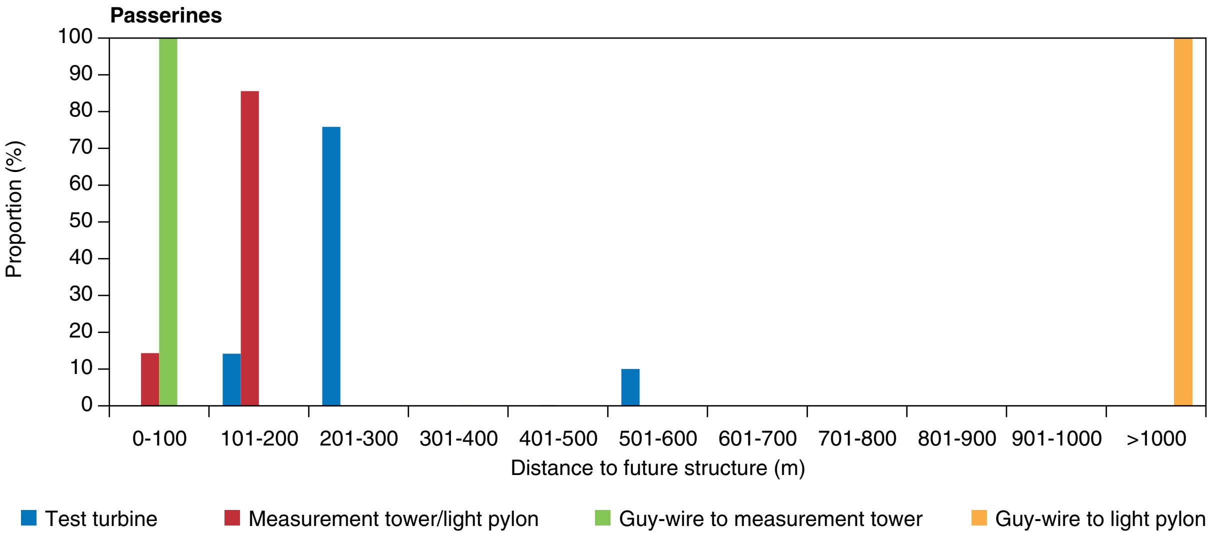


Figure 63. Distribution of minimum distances between flight paths of passerines and future structures at the test centre, late spring 2011 and September 2011-February 2012. The proportion is weighted by the number of individuals in the observed flocks.

There was a negative relationship between daily temperature and the numbers of passerines in the study area. This was presumably a result of passerines moving further south along the flyway in late autumn, when temperatures gradually dropped. Occurrence rate was highest in the evening, which may have been a result of birds being more active before settling into their night roosts (Tab. 25).

Table 25. Factors affecting the occurrence of passerines in the study area (N=399 count periods).

Sub-model	Factor	Estimate	SE	Wald χ2	P
Neg. bin. Numbers > 0	TEMP	-0.0855	0.0224	14.59	0.0001
Logistic	MONTH Feb	0			
	MONTH Jan	0.8908	0.6082	2.14	0.143
	MONTH Nov	3.2573	1.6176	4.05	0.0440
	MONTH Oct	1.7216	0.6368	7.31	0.0069
	MONTH Sep	1.1745	0.5511	4.54	0.0331
	TIME evening	-1.7528	0.5855	8.96	0.0028
	TIME mid-day	-0.9724	0.5451	3.18	0.0745
	TIME morning	0			

Altogether, 17.5% and 10.5% of the observed individuals and flocks, respectively, of passerines occurred at rotor height (50-250 m), whereas 81.9% and 89.3 of the remainder of individuals and flocks, respectively, were below rotor height (Fig. 64).

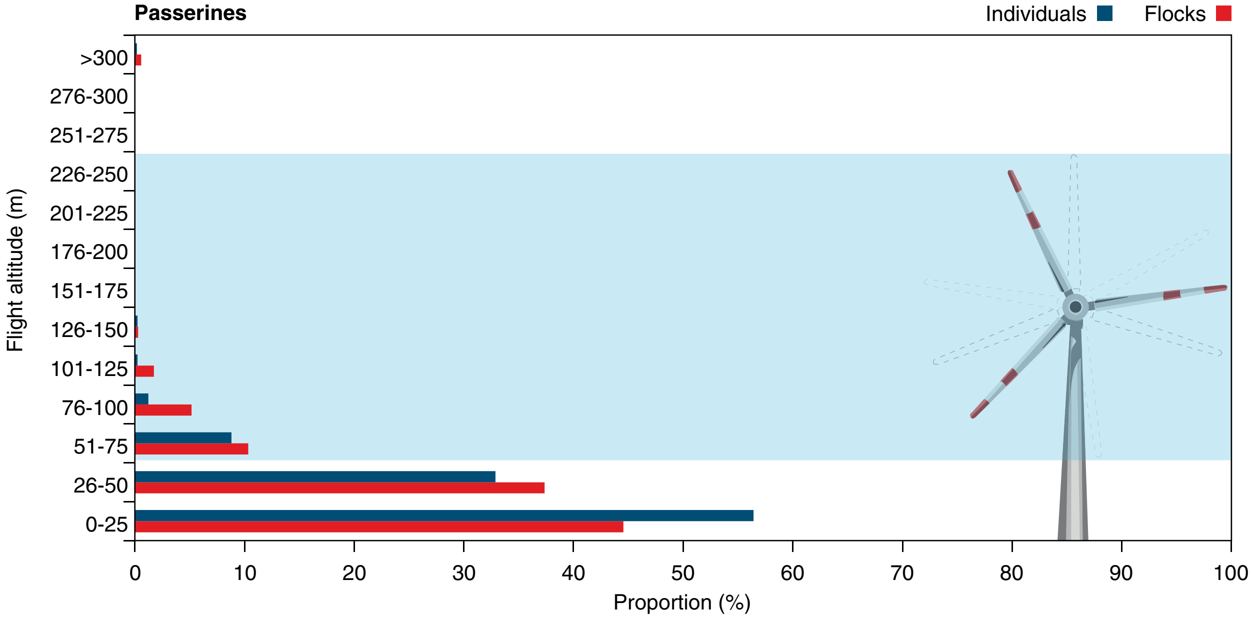


Figure 64. Flight altitudes of passerines expressed as the proportion of individuals (purple) and flocks (red) occurring at 13 altitude categories. The shaded blue box indicates the altitude categories covered by the sweep area of the wind turbines.

Preliminary estimate of collision risk at turbines and other structures

Since passerines were almost exclusively observed less than 600 m from the observation stations, no attempt was made to estimate collisions between passerines and wind turbines. Considering that a relatively small proportion of the passerines occurred at rotor height, we assess that collisions between wind turbines and passerines during daytime will be of a small magnitude.

It is important to notice that the difficulties detecting smaller passerines at distances beyond 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. Even though the calculated numbers (Tab. 24) may seem high, it is important to keep in mind that these should be divided between a range of species (App. A).

As expected, considering that the study area is not situated on a migration corridor, there were no indications that migrating passerines concentrated in the study area.

It should be noted that although the period covers most of the annual cycle, no data were collected in summer and early spring, when both local breeding birds and migrants occur 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 super-structures at the test centre. However, this may not be the case in situations, where visibility is reduced due to adverse weather conditions.

Preliminary assessment

In general, passerines are suggested to be among the bird species least susceptible to extra 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 we were unable to calculate number of collisions for this group of species, we consider the potential impact of the combined structures at the test centre on passerines active at daytime to be insignificant.

It should be noted that this preliminary assessment is based on a relatively limited amount of data collected during one season and must therefore be interpreted with caution. During the post-construction programme more data will be collected to improve the level of detail in the assessment of potential negative effects of the test centre on passerines at the species level.

Nocturnal migration

General occurrence

Patterns of nocturnal migration at the species level are difficult to obtain under most circumstances, although the speed of the flock, shape and size of radar echoes may give an indication of the type of migrants. On this basis, we consider 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, also occurred during night.

Temporal and spatial patterns of occurrence in the study area

Late spring (April 29-May 26 2011)

Nocturnal migrants were tracked throughout the study area. Tracks were predominantly in northerly direction (Fig. 65).

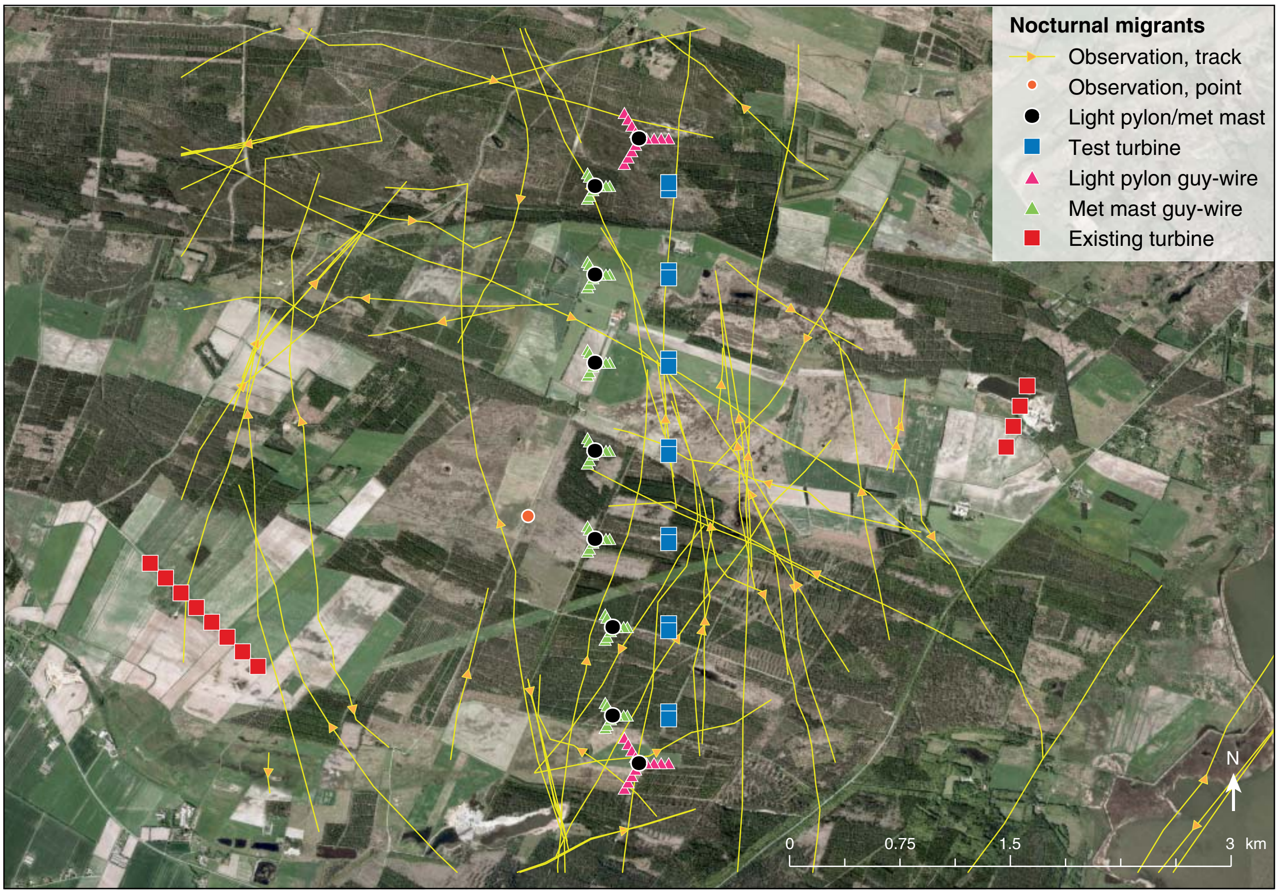


Figure 65. Overall flight patterns of nocturnal migrants, April-May 2011. Data were obtained by measurements with horizontal radar.

The altitudinal distribution of nocturnal migrants at night in April and May (Fig. 66, 67) showed that in general, flight altitude was highest in April. This was probably a result of real migrants dominating the sample, whereas in May, more local birds have arrived to the breeding grounds making shorter, local movements at lower altitudes.

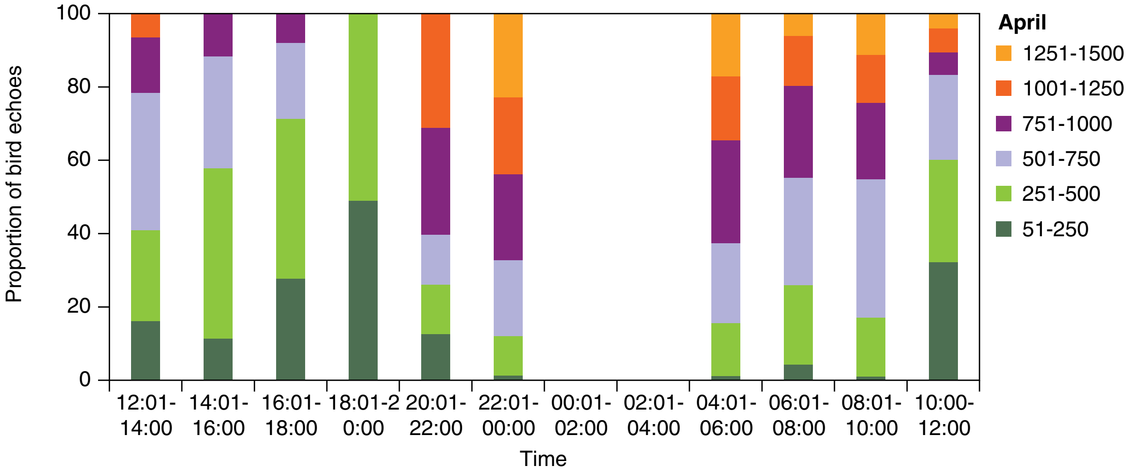


Figure 66. The relationship between time of the night and altitudinal distribution of nocturnal migrants, April 2011.

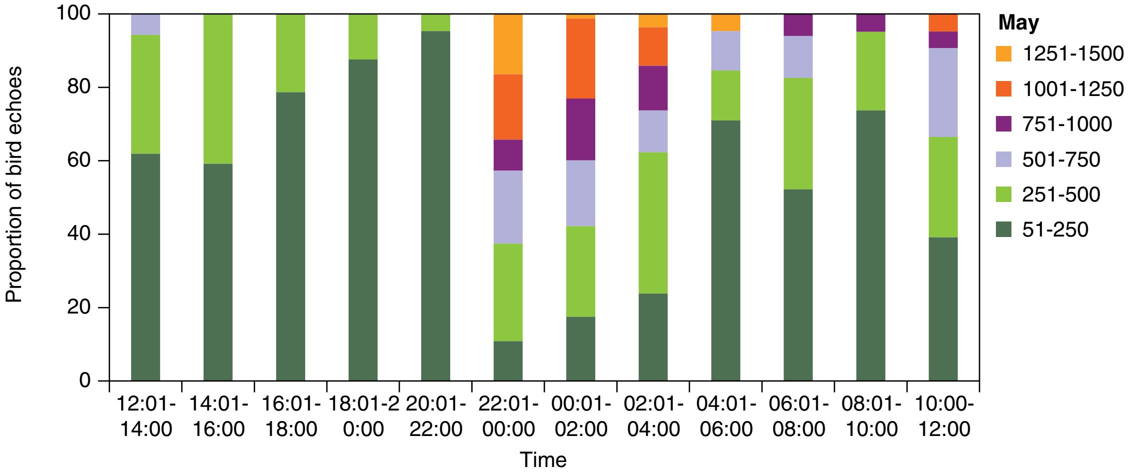
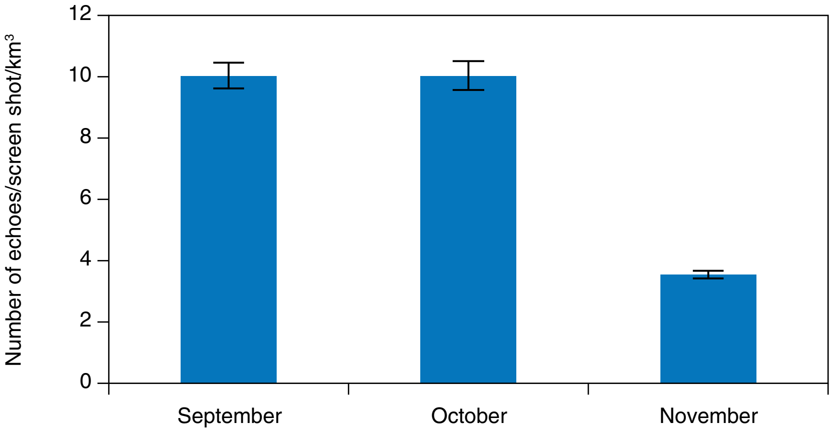


Figure 67. The relationship between time of the night and altitudinal distribution of nocturnal migrants, May 2011.

Autumn (September-November 2011)

In autumn 2011, migration intensity was highest in September and October, when a major influx of Northern Scandinavian passerines, e.g. thrushes, warblers, normally takes place (Fig. 68).

Figure 68. Migration intensity expressed as the number of echoes/screen shot/km^3 in September, October and November 2011.



Nocturnal migration intensity was highest in the morning and in the evening, which indicates that local birds were moving between feeding areas and night roosts around dusk. Migration intensity was highest during southwesterly winds, although the biological significance of this pattern is difficult to interpret (Tab. 26).

Table 26. Factors affecting the nocturnal migration intensity at the test centre, September-November 2011 ($R^2 = 0.147$, N=53324 echoes).

Factor	Estimate	SE	t	P
NE wind	-0.2879	0.1253	2.3	0.0218
NW wind	-0.4557	0.1789	2.55	0.011
SE wind	-0.9726	0.114	8.53	< 0.0001
SW wind	0			
Time^2	0.0017	0.0002	7.57	< 0.0001

The average flight altitude was highest during the middle of the night, which is a typical pattern of nocturnal migration (Kahlert, in press.). This is presumably 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 (Fig. 69).

The altitudinal distribution of nocturnal migrants during night in September, October and November (Fig. 70, 71, 72) showed that, in general, flight altitude was highest in October, when real migrants dominate the sample.

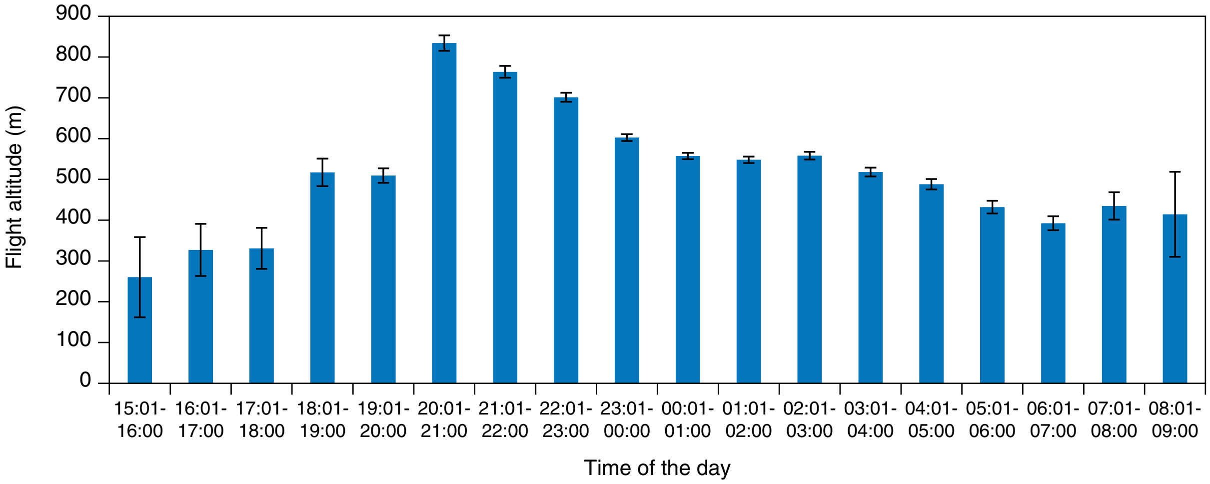


Figure 69. The relationship between flight altitude of nocturnal migrants and the time of the day.

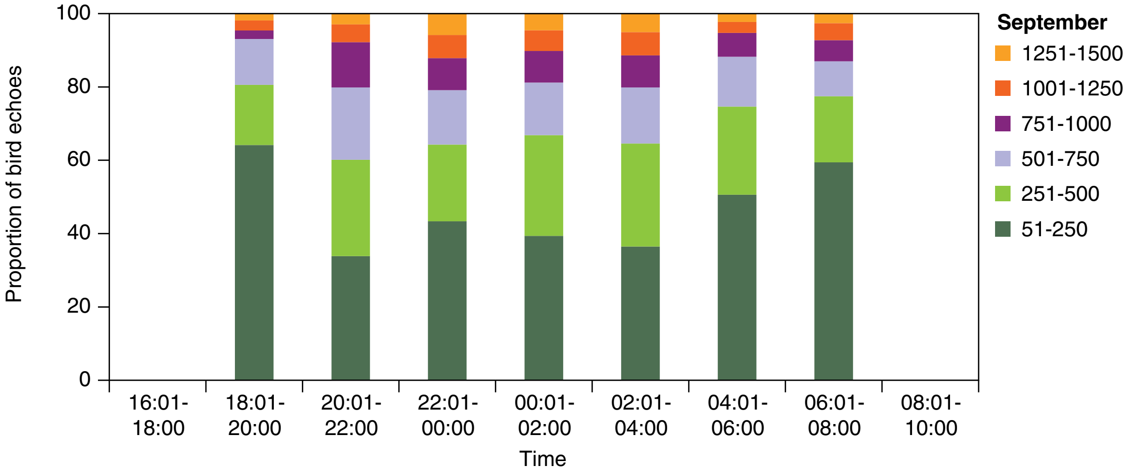


Figure 70. The relationship between time of the night and altitudinal distribution of nocturnal migrants, September 2011.

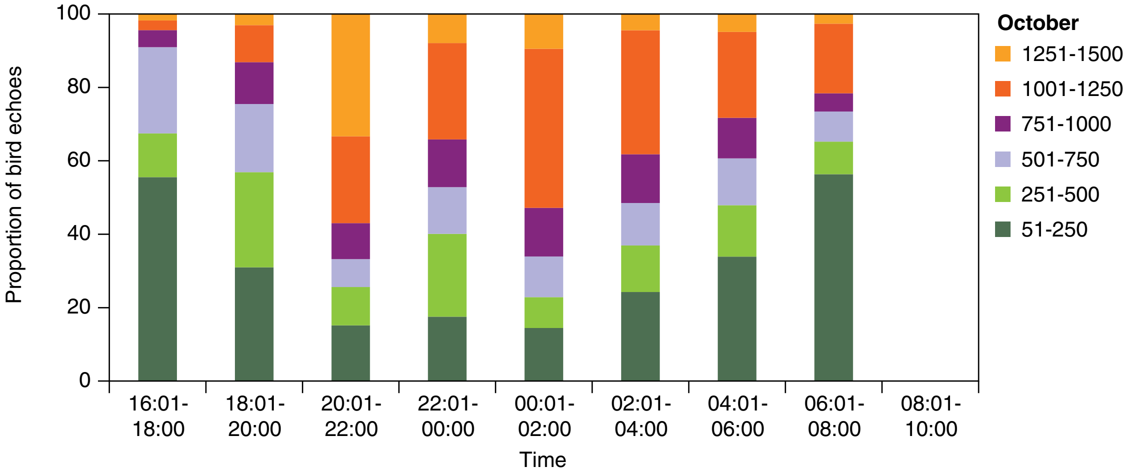


Figure 71. The relationship between time of the night and altitudinal distribution of nocturnal migrants, October 2011.

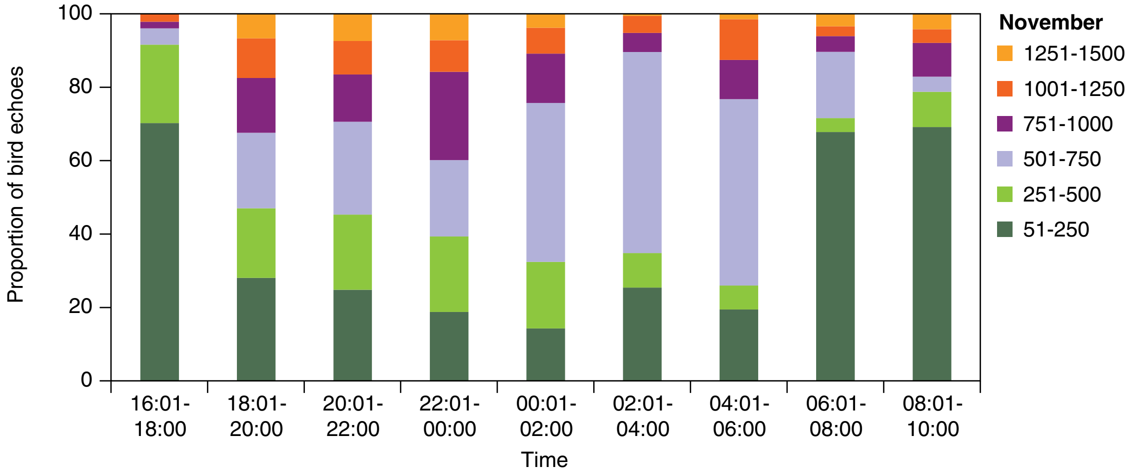
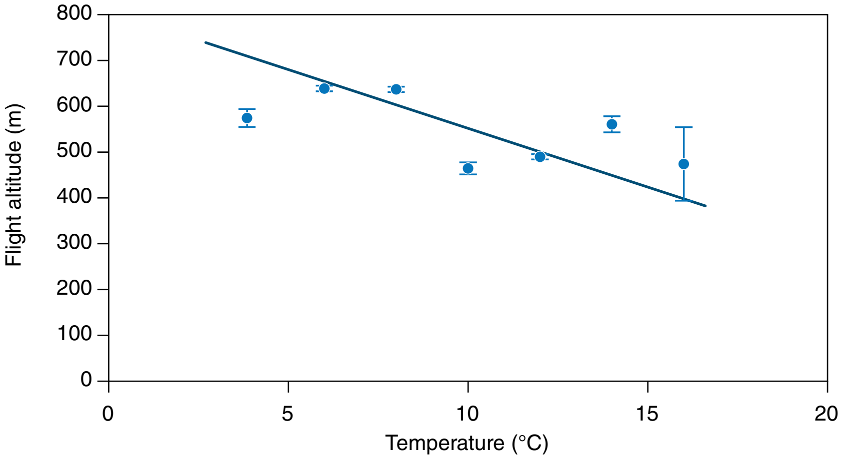


Figure 72. The relationship between time of the night and altitudinal distribution of nocturnal migrants, November 2011.

Figure 73. The relationship between temperature and flight altitude of nocturnal migrants (mean ± 95 % confidence limits) (trendline: y=808.28-25.65*temp).



Flight altitude of nocturnal migrants was inversely correlated with temperature (Fig. 73). This may reflect the fact that in November, when fewer local birds are present, real migrants at higher altitudes dominates the sample (Fig. 72, Tab. 26).

Flight altitude was positively correlated with wind speed (Tab. 27), which indicates that nocturnal migrants used tailwinds. The flight altitude was lowest at north easterly winds, which is somewhat surprising, since tailwinds would normally be expected to result in higher flight altitudes.

Table 27. Factors affecting the flight altitude of nocturnal migrants, September-November 2011 (R^2 = 0.134, N=53324 echoes).

Factor	Estimate	SE	t	P
WINDDIR NE	0			
WINDDIR SW	184.3	5.19	35.51	< 0.0001
WINDDIR SE	146.29	6.54	22.38	< 0.0001
WINDDIR NW	173.86	7.51	23.16	< 0.0001
SPEED	5.72	1	5.72	< 0.0001
TEMP	-45.71	0.81	56.28	< 0.0001
TIME2	-1.75	0.03	62.31	< 0.0001

Preliminary estimate of collision risk at turbines and other structures

The radar studies showed that genuine nocturnal migration occurred in the study area, although the pattern indicates that the test centre is not situated on a migration corridor. Indeed, the pattern of nocturnal migration merely suggests a broad-fronted movement of passerines, which is outnumbered by the activity of local birds around dusk, i.e. migration intensity was highest at this time of the day. If the test centre had been situated on a migration corridor, we would have expected the opposite, i.e. highest migration intensity during the middle of the night.

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.

Preliminary assessment

Natural mortality of nocturnally migrating passerines is high during autumn migration, which among other factors may be a result of a large proportion of naïve juveniles in the population being more vulnerable than adults to various kinds of hazard (Newton 2007).

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). However, given the indication that geese and swans commute between foraging areas within the study area, also during periods with dusk and darkness, the proportion of passerines, which was registered at this time, is likely to be smaller.

Although collision risk for nocturnal migrants is expected to be low, the post-construction programme will focus on collecting species-specific data on collision risk between nocturnal migrants and wind turbines and associated structures at the test centre. This will include the use of horizontal radar to obtain measurements of migration speed, which can be used to discern passerines and waterbirds, enabling us to identify periods dominated by either passerines or waterbirds. In addition, the use of carcass-searching dogs will be used to determine collision frequency of specific species groups, although this method may be insufficient to provide the data needed to accurately understand collision impacts, particularly for smaller passerines, which are more likely to be scavenged and go undetected during searches. Furthermore, in the post-construction study, the potential attraction effect on nocturnal migrants from the lights at structures at the test centre will also be considered. Altogether, this will improve the level of detail in the assessment of potential negative impacts on nocturnal migrants.

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 extra 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). However, in the present preliminary stage of the present project, we selected only the species (individuals or stages of the annual life cycle), which presently are most likely affected should any adverse effect occur (sensu Masden et al. 2010). The present list of recommended species is considered preliminary, and new species may be added as new knowledge emerges from the post-construction studies.

The baseline analyses of the collision risk at turbines and associated structures identified three species or species groups for which the annual collision rate exceeded one individual per structure (turbine, tower or light pylon). Using this threshold as a precautionary principle, golden plover, pink-footed goose together with day- and night-time migrating passerines were selected for further investigation. In addition, common crane, taiga bean goose and light-bellied brent goose, which are represented by small and or declining populations either locally, nationally or at the flyway-level and have low reproductive output, occurred regularly or in substantial numbers in the study area compared to the population size. Thus, these three species were also selected for further evaluation of the cumulative impacts and, hence, a total of five species were included in this analysis. However, a comprehensive list of man-induced pressures with quantitative measures of impacts is not possible to compile given the gaps in our present knowledge, even for well-studied species such as pink-footed goose.

Light-bellied brent goose

The population of light-bellied brent goose that occurs in Denmark is probably declining. The most important human-induced impact is eutrophication, which has caused a dramatic reduction in the distribution of Eelgrass *Zostera marina*, the most attractive food resource for the species. The intake of alternative food items such as crops in cultivated areas and saltmarsh plants has negative consequences for the daily energy budget of light-bellied brent geese at least during autumn (P. Clausen, pers. comm.). The impact on the annual mortality rate and reproductive output from habitat changes is, however, not possible to quantify at present. Although little is known about the magnitude, the species is subject to collisions at man-made super-structures (power lines, turbines, towers, etc.), especially in the wintering areas in Denmark and UK. The baseline study showed that the north-orientated spring migration towards the breeding areas is likely to traverse the study area. However, the collision risk at the test centre cannot be estimated at present. It is assessed that the light-bellied brent goose is amongst those goose species in Denmark, which are least resilient to extra mortality.

Taiga bean goose

Both the conservation status of the small population of taiga bean goose and the magnitude of impacts of human-induced pressures are unknown. As other goose species taiga bean goose is subject to an unknown number of collisions at man-made superstructures (power lines, turbines, towers etc.). Although protected on the wintering areas in most countries, no overview of hunting exists along the flyway. Given that the taiga bean goose population is small and feeding areas confined to relatively few areas, even small-scale disturbance may affect a large proportion of the population. Given the small order of magnitude of the collision risk predicted from the baseline studies at the Østerild Test Centre, there is presently no concern for the taiga bean goose. However, the uncertainties from a baseline study not covering important parts of the migration period combined with the unknown resilience of the population to added mortality dictate that more data on this species are collected during the post-construction studies, before robust conclusions on the cumulated impact of various sources of human activity, including the Østerild Test Centre can be drawn.

Pink-footed goose

A draft of an international species management plan for the Svalbard population wintering in North west Europe was published under the auspices of AEWA (African-European Waterbird Agreement) ratified by Denmark and other countries along the flyway of the population (Madsen & Williams, in prep.). This plan lists a number of present and potential future threats from human activity. This comprises man-induced habitat loss (due to climate change in the Arctic breeding areas, changes in economic policies and land use), hunting (including optimization of hunting regulations and practises to regulate the population size, mortality, crippling and illegal hunting) and disturbance (recreational activities, intentional scaring at agricultural conflicts and hunting). In addition, pink-footed goose is subject to an unknown magnitude of collisions and habitat loss at man-made super-structures (power lines, wind farms, towers etc.), mainly in the wintering areas. The hunting bag was assessed to be approximately 9,000 individuals in Denmark and Norway (J. Madsen, pers. comm.). Geese carrying shotgun pellets did not lead to detectable effects on body condition (Madsen & Riget 2007), despite being imposed on a substantial part of the population. However, crippled birds were not included in the analysis. The pink-footed geese occurring in West and Northwest Jutland have shown some habituation to wind turbines and forage much closer to these structures than previously observed (Madsen & Boertmann 2008). In nearby Klim Wind Farm an annual collision frequency of several hundred individuals was predicted for the worst case, although estimates were associated with great uncertainty and yet to be further investigated in a post-construction programme (Kahlert et al. 2012). It should also be noted that this case cannot be extrapolated to the circumstances at Østerild. Thus, the preliminary prediction of the collision risk for pink-footed goose at the test centre suggests a much smaller magnitude of the number of collisions (less than 50 covering most of the potential staging and wintering period), which compared to other impacts seems insignificant. In addition, it was concluded that pink-footed goose is quite resilient to extra mortality with an annual growth of the population of ca. 5%

in recent years, despite an increase in intentional scaring in farmland areas and the erection of new and larger turbines. Yet, it is still important that this preliminary assessment is supported by further information from the post-construction period in order to verify the preliminary predictions.

Common crane

The common cranes occurring in Denmark belong to the Northwest European population (230,000 individuals). An updated overview of the potential man-induced threats to common cranes had not been found. In the wintering areas in Spain power lines have previously been identified as the main cause of mortality amongst adult cranes (Meine & Archibald 1996). In a later study, an estimated 1 collision per 21,000 to 52,000 crossings of power lines were estimated (Janss & Ferrer 2000). Power line crossings probably constitute a prominent cause of mortality elsewhere along the flyway. Information on crane collisions is scarce at wind farms. A ground search study at nearby existing Klim Wind Farm did not report any casualties from a study period of 72 days, at one of the sites in Denmark with the largest local movement of common cranes. However, it was suggested that up to ca. 5 cranes would collide annually. Although not confirmed by recent information common cranes may still be subject to illegal hunting in Southwest Europe and land-use changes. Despite the threats, the population has undergone a marked increase in numbers in recent years. This suggests that the population is relatively resilient to extra mortality, which was confirmed at least for the Danish breeding population (Kahlert 2011). Hence, the small magnitude of the predicted mortality at the Østerild Test Centre (likely to be less than one individual annually) added on top of other human-induced pressures does not raise concern at present, although post-construction verification is necessary to obtain less uncertainty in predictions.

Golden plover

In the EU management plan for 2009-2011, Bechet (2009) presents a list of threats to golden plover in Europe. The management plan does not discriminate between the two sub-species occurring in Denmark, *Pluvialis apricaria apricaria* (a declining population to which the Danish breeding birds belong) and *Pluvialis apricaria altifrons* (an increasing population breeding north and northeast of Denmark). The list of possible man-induced threats includes climate change, which may reduce the availability of food items for chicks (predicted decline in overall breeding success of 11%). Furthermore, hunting is thought to have a low to medium impact on the populations with 95,000 individuals in the annual bag in the countries with an open season (France, Portugal and Malta). According to the definitions in Bechet (2009), this means that hunting is likely to cause fluctuations or even significant declines in the populations. Moreover, golden plovers are shot in the British Isles, but no bag records exist from there. Finally, habitat loss due to land use changes and recreational disturbance are identified as human activities that are considered to have low-medium importance. Especially in the UK, concern has been raised with respect to wind farm development and the potential associated habitat loss in breeding areas. An expected collision risk of less than 100 individuals annually at the test centre seems to suggest that the additional impact of establishing the test centre is unlikely to cause any measurable impact on the populations.

Day- and night-time migrating passerines

From the outset it may look alarming that possibly between 500 and 1,000 passerines may collide annually at the Østerild Test Centre. However, distributed over 38 species of day-time migrants observed during the baseline study and an unknown number of nocturnal migrant species, the collision risk becomes comparable to that predicted for individual species amongst other species groups. The list of potential man-made hazards encountered by passerines is extensive. In Denmark estimated 1.1-3.2 mill. birds are killed by road traffic annually of which ca. 85% corresponding to 0.9-2.7 mill. are passerines (Hansen 1982, Bruun-Scmidt 1994). These figures may even be minimum estimates as the number of cars has increased since the 1980s and 1990s, when data were compiled. Other important impact factors from human activity are collisions with structures, (e.g. towers, buildings, power lines, wind turbines, oil-rigs and gas installations at sea), which all together may cause many thousands of casualties. However, passerines are mainly short-lived species with a high annual reproductive output, which provides a potential for faster population recovery should they incur man-induced mortality, especially if there is strong density dependence. In addition, common passerine species which is for example occasionally found dead in large numbers at the Øresund Bridge are recruited from large populations (e.g. Sweden holds 3-6 mill. breeding pairs of robins, 1.5-3.0 mill. breeding pairs of song thrush and 2-5 mill. pairs of goldcrest; Svensson et al. 1999), which makes them robust to a high number of casualties. Therefore, it is presently assessed that the mortality imposed by the test centre additional to other sources of man-induced mortality is not of major concern. The post-construction studies will be more fine-grained including ground searches under the structures, and this will assist in discovering if certain species should incur unexpected high number of casualties that necessitates reconsideration of the preliminary assessment of the cumulative impact.

Conclusions and perspectives

This report presents 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, has been carried out. In addition, a number of species was included in the preliminary assessment on the basis of their regular occurrence in the study area. Finally, we present the first study of broad front nocturnal migration in this part of Denmark.

The baseline study confirmed that the test centre is not situated on a migration corridor, although seasonal migration took place to some extent both during night and day. 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 baseline programme. 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, we demonstrated local movements to take place on a regular basis for a number of species.

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). However, even though the four species were all characterized by a high proportion of individuals passing the study area at rotor height, this only resulted in a relatively limited number of predicted collisions.

For the remainder of the species that regularly occur in the study area, including the focal species whooper swan, taiga bean goose and common crane, 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.

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

However, it is important to keep in mind that the data collected during the baseline programme only covers one year. Therefore we are unable to 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 the baseline investigations will allow us to continue the collection of species-specific data during 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 focus on periods when species of potential concern occur in the study area.

Although the baseline programme covered most of the annual cycle, some important periods were not included in the study. Therefore the post-construction programme will fill out the gaps from the baseline programme by targeting those periods from which little or no current data are available.

Since the post-construction programme includes carcass searches by trained dogs, more reliable estimates of mortality factors, including background mortality and mortality related to the structures at the test centre, will be obtained. This will improve the crude estimates of the collision risk obtained during the baseline programme, and, furthermore, enable an estimation of local avoidance rates for the focal species. Likewise, the post-construction programme will focus on obtaining data to assess the extent to which the wind turbines and associated structure may attract nocturnal migrants.

It is important to note that the test centre will comprise the highest land based wind turbines established so far in Denmark. This means that structures will occupy strata used by migrants at higher altitudes than has previously been experienced.

By using the data compiled during the baseline programme, the post-construction programme, which is planned to take place in 2013/14 and 2015/16, will assess the possible effects and impacts on migrating birds, which may be caused by the operation of the test centre. In addition, the post-construction programme will assess the potential cumulative impacts of the wind turbines and other structures on migrating birds. Particularly, the baseline programme will be used as a reference to assess potential impacts at the population level (mortality caused by collisions) and effects related to behavioural questions (e.g. barrier effects, avoidance of and attraction to the combined structures at the test centre).

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Appendix B.1

Species group	Species	Transects Flocks	Transects Individuals	Measurements with laser range finder	Bird echoes vertical radar autumn and winter	Bird tracks / flocks horisontal radar late spring	Bird tracks / individuals horisontal radar late spring	Bird echoes vertical radar late spring
Birds of prey	Buzzard	63	80	258	0	6	11	4
Birds of prey	Sparrowhawk	24	27	37	0	2	4	0
Birds of prey	Kestrel	18	18	81	0	0	0	0
Birds of prey	Hen harrier	4	4	29	0	0	0	0
Birds of prey	Goshawk	3	3	13	0	0	0	0
Birds of prey	Rough-legged buzzard	3	3	3	0	0	0	0
Birds of prey	Marsh harrier	2	2	4	0	1	1	1
Birds of prey	Merlin	2	2	2	0	0	0	0
Birds of prey	Osprey	2	2	16	0	0	0	0
Birds of prey	Peregrine falcon	2	2	25	0	0	0	0
Birds of prey	Red kite	1	1	4	0	0	0	0
Birds of prey	White-tailed eagle	1	1	0	0	0	0	0
Birds of prey	Golden eagle	0	0	1	0	0	0	0
Cormorants	Cormorant	147	429	349	0	151	656	6
Cranes	Common crane	12	48	106	0	5	16	1
Crows	Hooded crow	323	796	426	0	0	0	0
Crows	Jackdaw	18	217	36	0	2	14	0
Crows	Jay	37	45	60	0	0	0	0
Crows	Common raven	7	14	38	0	0	0	0
Crows	Magpie	6	9	2	0	0	0	0
Crows	Carrion crow	4	5	5	0	0	0	0
Crows	Rook	1	2	2	0	0	0	0
Doves	Wood pigeon	107	309	121	0	3	18	0
Doves	Collared dove	2	8	1	0	0	0	0
Dabbling ducks	Mallard	3	19	2	0	0	0	0
Dabbling ducks	Shelduck	5	8	4	0	0	0	0
Diving ducks	Goldeneye	0	0	1	0	0	0	0
Geese	Pink-footed goose	102	7116	670	0	15	656	0
Geese	Greylag goose	92	1022	355	0	8	63	0
Geese	Pink-footed/bean goose	2	510	0	0	0	0	0
Geese	Taiga bean goose	13	131	117	0	0	0	0
Geese	White-fronted goose	0	0	6	0	0	0	0
Geese	Anser sp.	0	0	0	0	3	25	0
Geese	Light-bellied brent goose	0	0	2	0	6	279	1
Geese	Barnacle goose	0	0	4	0	0	0	0
Geese	Canada goose	0	0	0	0	1	19	0
Gulls and terns	Herring gull	65	131	78	0	23	60	7
Gulls and terns	Great black-backed gull	44	76	93	0	11	43	0
Gulls and terns	Black-headed gull	35	58	9	0	1	2	1
Gulls and terns	Less black-backed gull	7	24	17	0	0	0	0
Gulls and terns	Common gull	4	5	10	0	0	0	0
Gulls and terns	Common tern	1	1	1	0	0	0	0

Herons	Grey heron	3	3	21	0	2	2	0
Owls	Short-eared owl	0	0	1	0	0	0	0
Passerines	Starling	52	1774	50	0	0	0	0
Passerines	Chaffinch	48	544	30	0	0	0	0
Passerines	Corn bunting	15	477	26	0	0	0	0
Passerines	Yellowhammer	44	339	50	0	0	0	0
Passerines	Fieldfare	16	239	30	0	0	0	0
Passerines	Meadow pipit	32	170	23	0	0	0	0
Passerines	Skylark	32	109	47	0	0	0	0
Passerines	Barn swallow	18	44	13	0	0	0	0
Passerines	Redwing	5	39	13	0	0	0	0
Passerines	Common crossbill	7	37	6	0	0	0	0
Passerines	Siskin	4	37	2	0	0	0	0
Passerines	Linnet	8	19	4	0	0	0	0
Passerines	Tree sparrow	1	11	2	0	0	0	0
Passerines	White wagtail	8	10	2	0	0	0	0
Passerines	Goldfinch	2	9	0	0	0	0	0
Passerines	Finch sp.	1	7	0	0	0	0	0
Passerines	Greater spotted woodpecker	6	7	6	0	0	0	0
Passerines	Blackbird	4	5	9	0	0	0	0
Passerines	Great grey shrike	5	5	17	0	0	0	0
Passerines	Greenfich	4	5	1	0	0	0	0
Passerines	House martin	3	4	1	0	0	0	0
Passerines	Water pipit	3	4	3	0	0	0	0
Passerines	Wheatear	3	4	0	0	0	0	0
Passerines	Brambling	1	3	1	0	0	0	0
Passerines	Lapland Bunting	3	3	2	0	0	0	0
Passerines	Reed bunting	1	3	4	0	0	0	0
Passerines	Snow bunting	2	2	2	0	0	0	0
Passerines	Twite	1	2	1	0	0	0	0
Passerines	Cuckoo	1	1	3	0	0	0	0
Passerines	Hawfinch	1	1	1	0	0	0	0
Passerines	Horned lark	1	1	1	0	0	0	0
Passerines	Mistle thrush	1	1	2	0	0	0	0
Passerines	Redpoll	1	1	4	0	0	0	0
Passerines	Swift	1	1	0	0	0	0	0
Passerines	Waxwing	1	1	1	0	0	0	0
Passerines	Grey wagtail	0	0	1	0	0	0	0
Passerines	House sparrow	0	0	1	0	0	0	0
Passerines	Two-barred crossbill	0	0	1	0	0	0	0
Passerines	Red-throated pipit	0	0	1	0	0	0	0
Swans	Whooper swan	64	291	516	0	0	0	0
Swans	Tundra swan	6	55	47	0	0	0	0
Swans	Mute swan	1	2	5	0	1	1	0
Waders	Golden plover	22	8425	36	0	13	805	0
Waders	Lapwing	18	694	41	0	0	0	0
Waders	Common snipe	14	42	19	0	0	0	0
Waders	Bar-tailed goodwit	1	17	0	0	0	0	0
Others	Unknown species	0	0	0	53324	75	unknown	1376

Appendix B.2

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 πR2 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 windfarm multiplied by the height of the rotors.

2. Calculate the combined volume swept out by the windfarm rotors Vr = N x πR2 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 were based on the recommendations of Scottish Natural Heritage (Urquhart 2010).

Species	Avoidance rate (%)	Source
Cormorant	98.00	Urquhart 2010
Whooper swan	98.00	Urquhart 2010
Tundra swan	98.00	Urquhart 2010
Pink-footed goose	97.75-99.00	Kahlert et al. 2010
Taiga bean goose	99.00	Urquhart 2010
Greylag goose	97.89-99.00	Kahlert et al. 2010
Hen harrier	99.00	Urquhart 2010
Buzzard	98.00	Urquhart 2010
Peregrine falcon	98.00	Urquhart 2010
Common crane	98.00	Urquhart 2010
Golden plover	98.00	Urquhart 2010
Wood pigeon	98.00	Urquhart 2010
Common Raven	98.00	Urquhart 2010

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 ϕ 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 $= (1/\pi R2) \iint p(r, \phi)\, r\, dr\, d\phi = 2\int p(r)\, (r/R)\, d(r/R)$ (1),

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

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, Ω = angular velocity of rotor (radians/sec), c = chord width of blade

γ = pitch angle of blade, R = outer rotor radius, l = length of bird, w = wingspan of bird, β = 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 ϕ) $= (2/\pi)$ 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 γ, 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 ϕ) or is gliding ($p(r, \phi)$ is ϕ 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 α, c and γ 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 slipstream 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 DOF-basen (www.dofbasen.dk/ART), while flight speeds was 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
Bean goose	0.67	1.61	17.3
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
Hen harrier	0.47	1.10	9.1
Buzzard	0.54	1.21	12.5
Wood pigeon	0.41	0.78	17.0
Raven	0.64	1.35	14.3

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

Specification	Value
Area of wind farm	462 ha
Number of turbines	7
Hub height	150 m
Rotor altitude	50-250 m
Rotor diameter	200 m
Time per rotation	9.05 sec
Wing breadth	6 m

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BASELINE INVESTIGATIONS 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 prior to the construction of a national test centre for wind turbines near Østerild in Thy, Denmark. The occurrence and activity level of bats in Østerild Plantation and the vicinity were monitored in summer and autumn 2011. Bats were recorded on 57-100% of surveyed nights at individual wind turbine sites, ponds and lakes. A total of seven species were recorded. Pond bats were recorded at all sites and throughout the survey period in the plantation. Whooper swan, taiga bean goose, pink-footed goose and common crane 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 a preliminary 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 preliminary assessment, the post-construction programme will further investigate potential impacts on bats and birds.

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