Kriegers Flak
Offshore Wind Farm

Birds and Bats
EIA - Technical Report
June 2015

NIRAS

DHI

AARHUS UNIVERSITET
INSTITUT FOR BIOSCIENCE

This report is prepared for Energinet.dk as part of the EIA for Kriegers Flak Offshore Wind Farm. The report is prepared by Danish Center for Environment and Energy (DCE) at Aarhus University and DHI in collaboration with NIRAS.

Birds and bats at Kriegers Flak

Baseline investigations and impact assessment for establishment of an offshore wind farm

June 2015

This report has been prepared under the DHI Business Management System
certified by DNV to comply with ISO 9001 (Quality Management)

QUALITY SYSTEM CERTIFICATION
ISO 9001
DNV
DNV Business Assurance, Danmark A/S

Kriegers Flak Offshore Wind Farm

Environmental Impact Assessment

Technical background report

Birds and bats

Photo by Thomas W. Johansen

Prepared for	Energinet.dk
Represented by	Anders Nielsen/Pernille Holm Skyt

Project manager	Henrik Skov
Author	Henrik Skov, Mark Desholm, Stefan Heinänen, Thomas W. Johansen, Ole R. Therkildsen
Quality supervisor	Ramūnas Žydelis

Project number	11813670
Approval date	June 2015
Revision	Final
Classification	Public

Contents

1 Non technical summary

The present report covers the baseline and environmental impact assessment for the planned Danish Kriegers Flak Offshore Wind Farm in relation to birds and bats. The planned Kriegers Flak OWF (600 MW) is located app. 15 km east of the Danish coast in the southern part of the Baltic Sea close to the boundaries of the exclusive offshore economic zones (EEZ) of Sweden, Germany and Denmark. The wind farm is part of the Danish Energy 21 action plan and the energy scenarios 2014 defined by the Energy Agency, which aim to increase the proportion of offshore wind energy to a level of 72% in the year 2030 and construct a capacity annually equivalent of a 400 MW offshore wind farm between 2020 and 2050. The Project Area for the Kriegers Flak OWF is located in the central part of the Arkona Basin. The turbines will be constructed on the shallow sandbank Kriegers Flak, which shares characteristics with other shallow offshore banks in the western Baltic in terms of a relatively high biomass of blue mussels which supports relatively high densities of Long-tailed Ducks. Conservation-wise, the most significant feature of the site is its location midway between Sweden and Germany in a region which is considered strategically important for landbird migration, here especially raptors and Common Crane, which are sensitive to collision. Thus, the baseline investigations and impact assessment on wintering waterbirds focused on seaducks, whereas the investigations and assessment on bird migration mainly covered migration of raptors and Common Crane. In addition, the assessment covers migrating bats which may cross Kriegers Flak én route between Scandinavia and mainland Europe.

The baseline assessment on waterbirds was based on a recent review of wintering waterbird populations in the Baltic Sea, Danish waterbird monitoring data from 2004 and 2008 and baseline surveys undertaken in relation to the planned wind farms on the Swedish and German parts of Kiegers Flak. In order to generalise patterns of waterbird distribution over time and space in the region predictive distribution modelling was applied for the most prevalent waterbird species in the region, i.e. Long-tailed Duck, Common Scoter and Velvet Scoter. Distribution and abundance of waterbirds were assessed for two different time periods, as substantial changes in bird densities between mid-90s and more recent surveys (2008-2009) has been reported. Compared to the size of the biogeographic population Long-tailed Duck is the most important waterbird species on Kriegers Flak where it occurs between November and May. Shallow water, coarser sediments, large growth potential for mussels, large distances to land and moderate sloping bottoms constituted the main habitat variables for the Long-tailed Duck. The highest densities were predicted in southern parts of the study area in the Pomeranian Bay and west of Rügen, other areas also used by the long tailed ducks were coastal areas and offshore banks like Kriegers Flak. Densities were much higher during period 1 (1987-1993), - approximately a factor 10 compared to Period 2 (2004-2009). This was also evident on Kriegers Flak where maximum densities of 100 birds/km^2 were predicted in Period 1 compared to densities of 10 birds/km^2 in Period 2. The area covered by the cable trace to Rødvig was characterised by low densities of waterbirds during both periods.

Baseline investigations undertaken in relation to the planned wind farms on the Swedish and German parts of Kriegers Flak and Adler Ground have provided the main sources of recent information on the timing and intensity of bird migration through the Arkona Basin. However, no or limited information was available concerning the magnitude and flight altitude of Common Crane and raptors as they cross the Arkona Basin each autumn and spring. In the international perspective, the Common Crane is the most important species in relation to assessments of risk of collision at the Kriegers Flak Offshore Wind farm. In order to estimate the flight altitudes in the offshore parts of this region satellite telemetry and radar tracking from the FINO 2 platform was applied during autumn 2013. Very high resolution tracks of 6 Common Crane were successfully recorded providing unique information about flight trajectories and altitudes as Common Crane cross large expanses of water in different meteorological conditions. Radar tracking of individual species of raptors and Common Crane was carried out from the FINO 2 research platform in the German part of Kriegers Flak, where tracking was done using a high-performance solid state radar (SCANTER 5000) with enhanced capacity for tracking over long distances and suppression of sea clutter. In addition, laser rangefinders were used to collect species-specific data on migrating birds both from the FINO 2 platform, from the Falsterbo Rev Lighthouse and from the coasts of eastern Denmark and southern Sweden. In order to generalise the satellite tracking, radar and rangefinder observations flight models were developed which coupled flight heights to weather parameters using Generalised Additive Mixed Models.

A total of 21 field days were covered during migration observations in spring and 32 in autumn, which means that observations were made during approximately 30% of the daytime migration periods for Common Crane and raptors. Most raptors tracked as they were leaving south Sweden in autumn had migration angles indicating that less than 10% cross the Arkona Basin. However, higher proportions were recorded for Red Kite (12%), Osprey (17%), Hen Harrier (37%) and Kestrel (19%). For Common Crane, however, the vast majority of directions from Falsterbo in autumn 2013 were concentrated around S in the direction of Rügen, and almost all birds crossed the Arkona Basin. The patterns of flight altitude displayed by the recorded raptors displayed a wide range of altitudes as the birds leave land, followed by descending altitudes as the birds cross the Baltic Sea. The angle of descend was significantly different between species, and often differed with wind directions with the steepest angle in tail winds when birds often initiate migration at higher altitudes.

The resulting frequency distributions of flight altitudes at the departure points on the Swedish coast, at the arrival points on the Danish east coast and at FINO 2 on Kriegers Flak clearly document that almost all raptors cross the central western Baltic at altitudes below 150 m. According to the model predictions the birds fly on average within rotor height of all turbine types at Kriegers Flak during all wind conditions, yet slightly higher in tailwinds in comparison to headwinds. The patterns of flight altitude displayed by migrating Common Crane were very similar to those observed for the raptors, yet a higher proportion of the Common Crane may cross Kriegers Flak at altitudes above 200 m. The general descend in flight altitude from the Swedish coast in autumn is nonetheless very clear. During spring, most Common Crane arrive to Denmark and Sweden at altitude between 150 and 200 m. During autumn steep descends are seen in both tail wind and head wind, the descend being slightly steeper in head winds. On average birds seem to cross the Arkona Basin at lower altitude during tail winds than head winds in autumn. According to the predictions of the flight models the Common Crane fly on average at rotor height of the 10 MW turbines but slightly above the 3 MW turbines during all wind conditions.

The existing knowledge on the presence of migratory bats of the Baltic Sea is very limited, and the purpose of the baseline study was primarily to record the species typically found in the region around Kriegers Flak. Two bat detectors (Wildlife Acousticks SM2) were installed at the FINO 2 research platform between August and November 2013. The Nathusius's Pipistrelle Bat was recorded in higher numbers on Kriegers Flak than other species of bats. Particularly on the 11 September when 215 recordings of animals were made. This recording indicated that mass migration as we see it in landbird migration may take place in this species offshore. This species has the largest migration distance between summer and winter quarters among the Nordic bats, and is considered as a long-distance migrant. The main migration direction is southwest. In addition, Noctule Bat, Parti-coloured Bat and Serotine Bat were recorded.

The spatial scale of the effect of habitat displacement on Long-tailed Ducks due to the disturbance from the turbine structures of the Kriegers Flak OWF is comparable to the scale of displacement due to disturbance from vessels, i.e. 3 km including footprint. Hence, the displacement area will be the same (302 km^2) and the annual number of displaced birds at the same level as during the construction phase. Between 160 and 1300 Long-tailed Ducks may be displaced annually. As the operation period may last 20 years or more, the total effect of habitat displacement during operation will be larger (moderate extent) than during construction, even if the affected number amounts to less than 1 ‰ of the total population of wintering Long-tailed Ducks in the Baltic Sea, and therefore is insignificant at the population level. Displacement impacts on waterbirds along the route of the cable trace are assesses as negligible. Estimates of number of collisions with migrating raptors and Common Crane were derived using the Band 2012 model based on the assumption of single transits of the same individual. The model was applied using bird crossings of the 10 MW layout (expected worst case) for raptor species and for the 10 MW, 8 MW, 6 MW, 4 MW and 3 MW layouts for Common Crane. A mortality of 50% was assumed for flocks colliding with the turbines. The avoidance rates applied in collision models were -0.24 (attraction) for raptors using data from Rødsand 2 offshore wind farm and 0.69 for Common Crane using data collected during a dedicated study at the Baltic 2 wind farm on the German part of Kriegers Flak in spring 2015. The dedicated study was undertaken from the FINO 2 platform using a combination of radar and rangefinder tracking as Common Crane were approaching and crossing the Baltic 2 wind farm. The study revealed very low levels of macro avoidance (close to zero) as Common Crane would enter the wind farm without hesitation. Moderate horizontal and vertical meso avoidance were recorded in the wind farm.

The significance of the predicted collision rates at the Kriegers Flak OWF was assessed by comparison with the compensatory potential of affected populations of raptors and Common Crane. This was done using thresholds for sustainable removal from the relevant bio-geographic bird populations concerned following the so-called PBR (Potential Biological Removal) concept.

Collision impacts for all raptors and Common Crane were assessed as minor for the Kriegers Flak project (predicted annual number of collisions was 216-296 Common Crane depending on turbine type) together with the existing Baltic 1 and Baltic 2 wind farms with a total predicted annual mortality caused by collisions ranging from 366 to 446. This assessment is based on the significance of the collision impact *sensu* its magnitude relative to the PBR threshold.

It should be stressed that these estimates rest on two assumptions which if proven wrong could cause the number of collisions to increase above the PBR threshold. It was assumed that the Common Crane during both spring and autumn migration would disperse throughout the Arkona Basin. Accordingly, even if Kriegers Flak is located centrally on the route between southern Sweden and Rügen the site would not have a higher density of flying Common Crane than other parts of the region. Secondly, the PBR threshold has been established assuming no important anthropogenic mortality on the population. Important sources of mortality which may lower the PBR threshold would include collisions with the Baltic 2 OWF and power lines. A third assumption may actually have resulted in a more conservative assessment. During spring 2015 the Baltic 2 offshore wind farm was not fully operational, the turbines in southern two rows of the wind farm had not been installed and the remaining rotors were idling. As a result, the Common Crane may have displayed less avoidance of the turbines compared to the situation when they are fully operational.

Large numbers of seaducks are likely to use this area én route between the wintering areas in the Danish Straits-North Sea and their breeding grounds. Although the spatial characteristics of the waterbird migration have not been mapped in detail it is most likely that the migration occurs over a broad front with weak tendencies for aggregations along the coasts of Sweden and Germany. The cross-sectional diameter of the wind farm will span roughly 13% of the width of the Arkona Basin, and consequently barrier effects on migrating waterbirds are likely to be small.

Only minor disturbance effects of bats from vessels are envisaged during construction, yet during operation of the wind farm collision risks are obviously pertinent. Although no bat casualties at offshore wind farms have yet been documented, migrating bats can be attracted by the turbine blades and towers if and when insects are gathered there. Thus, collision impacts are assessed as low-moderate.

Several wind farms are planned or consented in the region of Kriegers Flak, in total 12 wind farms. Once built, the impacts on birds will be similar to the impacts on birds from the Danish Kriegers Flak and the German Baltic 1 and 2 projects, i.e. collision impacts on migrating Common Crane crossing the region. The cumulative collision impacts on Common Crane from the consented four German projects with the Danish Kriegers Flak, Baltic 1 and Baltic 2 projects were assessed as moderate as the total estimated number of annual mortality caused by collisions (1,112-1,192) would constitute 60% of the PBR threshold for a stable population. If all 12 planned and consented projects with Kriegers Flak and the existing Baltic 1 and 2 projects would be built the annual cumulative collision impact on Common Crane would be very large (2,620-2,700) or at the PBR level for an increasing population. Hence, in view of unaccounted mortality factors in the calculation of the PBR threshold these predictions mean that the wind farms may cause an annual mortality which cannot be sustained by the Swedish-Norwegian breeding population. In such a case, a significant cumulative effect on EU Special Protection Sites classified under the Birds Directive for Common Crane from the Swedish-Norwegian population may be pertinent. This may be the case even if only the consented German wind farms and Kriegers Flak are built, as the Crane population will be subject to other mortality factors which have not been accounted for in the estimation of the PBR threshold. Accordingly, although there is no indication of Likely Significant Effect (LSE) from Kriegers Flak OWF alone or with the existing Baltic 1 and 2 wind farms, an adverse effect arising from in-combination collision risk, associated with the operational phase of Kriegers Flak OWF, Baltic 1 OWF, Baltic 2 OWF and the 4 consented other wind farms in the Arkona region cannot be precluded. The same conclusion is made with respect to in combination impacts with the 8 other planned wind farms in the region.

2 Ikke teknisk resumé

Nærværende rapport dækker forundersøgelser og VVM for den planlagte danske Kriegers Flak Havmøllepark i relation til fugle og flagermus. Den planlagte Kriegers Flak Havmøllepark ligger i Østersøen ca. 15 km øst for Møn og grænser nordøstligt op mod svensk søterritorium og sydøstligt mod tysk søterritorium. Vindmølleparken er en del af handlingsplan Energi 21, som har til formål at øge andelen af offshore-vindenergi til et niveau på 72% i år 2030. Projektområdet for Kriegers Flak Havmøllepark ligger i den centrale del af Arkona Basinnet. Møllerne vil blive bygget på den lavvandede sandbanke Kriegers Flak, som deler karakteristika med andre lavvandede offshore banker i den vestlige Østersø i form af en relativ høj biomasse af blåmuslinger, der understøtter relativt høje tætheder af havlitter. Den i naturbeskyttelsessammenhæng mest markante karakter ved området er dets placering midt mellem Sverige og Tyskland i en region, som anses for strategisk vigtig for landfugletræk, her især rovfugle og traner, der er følsomme over for kollision. Derfor har forundersøgelser af overvintrende vandfugle fokuseret på dykænder, mens undersøgelserne og vurdering af fugletrækket hovedsagelig har dækket trækket af rovfugle og traner. Desuden dækker vurderingen også migrerende flagermus, som kan krydse Kriegers Flak undervejs mellem Skandinavien og det europæiske fastland.

Vurdering af vandfugle blev baseret på en nylig gennemgang af overvintrende vandfuglebestande i Østersøen, danske vandfugle overvågningsdata fra 2004 og 2008 og forundersøgelser foretaget i forhold til de planlagte vindmølleparker på de svenske og tyske dele af Kriegers Flak. For at generalisere mønstre af vandfugle fordeling over tid og rum i regionen blev statistiske modeller anvendt for de mest udbredte vandfuglearter i regionen, d.v.s. havlit, sortand og fløjlsand. Udbredelse og antal vandfugle blev vurderet for to forskellige tidsperioder, idet væsentlige ændringer i tæthederne af vandfugle er blevet konstateret i regionen mellem midten af 90'erne og nyere undersøgelser (2008-2009). I forhold til størrelsen af den biogeografiske population er havlit den vigtigste vandfugleart på Kriegers Flak, hvor den findes mellem november og maj. Lavt vand, grovere sediment, stort potentiale for muslingevækst, store afstande til land og moderat bundrelief udgør de vigtigste habitat variabler for havlit. De højeste tætheder blev estimeret i de sydlige dele af undersøgelsesområdet i Pommerske Bugt og vest for Rügen, samt visse kystområder og offshore banker som Kriegers Flak. Tæthederne af havlit var langt højere midt i 90’erne - cirka en faktor 10 i forhold til den nuværende periode. Dette var også tydeligt på Kriegers Flak, hvor maksimale tætheder på 100 fugle/km^2 blev estimeret i 1990’erne sammenlignet med tætheder på 10 fugle/km^2 i den nuværende periode. Området for kabeltraceet til Rødvig var i begge perioder karakteriseret ved lave tætheder af vandfugle.

Forundersøgelserne i forbindelse med de planlagte vindmølleparker på de svenske og tyske dele af Kriegers Flak og Adler Grund er de vigtigste kilder til oplysninger om timing og intensiteten af fugletrækket gennem Arkona Bassinet. Til gengæld findes der kun begrænsede oplysninger om omfanget og flyvehøjden af traner og rovfugle, når de krydser Arkona Basin hvert efterår og forår. I det internationale perspektiv, er tranen den vigtigste art i forbindelse med vurderingen af risiko for kollision ved Kriegers Flak Havmøllepark. For at estimere flyvehøjder i offshore delene af denne region blev der i efteråret 2013 anvendt satellit telemetri og radar sporing fra FINO 2-platformen. I alt seks tranespor i høj opløsning gav unikke oplysninger om flyvebaner og højder når tranerne krydser store vandområder under forskellige meteorologiske forhold. Radar sporing af de enkelte arter af rovfugle og traner blev udført fra FINO 2 forskningsplatform i den tyske del af Kriegers Flak, hvor sporing blev gjort ved hjælp af en solid state radar (SCANTER 5000) med øget kapacitet til sporing over lange afstande og filtrering af støj fra bølger og regn. Desuden blev der anvendt laserkikkerter til at indsamle artsspecifikke data om trækkende rovfugle og traner fra både FINO 2 platformen, fra Falsterbo Rev Fyr og fra kysterne i det østlige Danmark og det sydlige Sverige. For at generalisere satellitsporingsdata, radar og laserkikkert data i forhold til forskellige vejrsituationer blev der udviklet rumlige modeller for fuglenes flyvehøjde ved hjælp af Generalised Additive Mixed Models.

I alt blev der dækket 21 feltdage under trækobservationerne i foråret og 32 i efteråret, hvilket betyder, at observationerne dækkede cirka 30% af dagtimerne i trækperioderne for traner og rovfugle. De fleste rovfuglespor registreret fra Sydsverige i efteråret havde trækvinkler der indikerer, at mindre end 10% krydsede Arkona bassinet. Imidlertid blev højere andele registreret for rød glente (12%), fiskeørn (17%), blå kærhøg (37%) og tårnfalk (19%). Til gengæld fløj langt størstedelen af tranerne i efteråret stik syd i retning af Rügen, og næsten alle fugle forventes at have krydset Arkona bassinet. Mønstrene i flyvehøjde viser, at de registrerede rovfugle viste en bred vifte af højder, når fuglene forlader land, fulgt af faldende højder som fuglene krydser Østersøen. Vinklen på nedstigningen var signifikant forskellig mellem de enkelte rovfuglearter, og varierede ofte med vindretningen med den stejleste vinkel under medvind, når fuglene ofte indleder trækket fra stor højde. De resulterende frekvensfordelinger af flyvehøjder fra den svenske kyst, på ankomstpunkter på den danske østkyst og FINO 2 på Kriegers Flak dokumenterede klart, at næsten alle rovfugle krydser den centrale vestlige del af Østersøen i højder under 150 m. Ifølge modellens forudsigelser flyver fuglene i gennemsnit i rotor højde af alle mølletyper ved Kriegers Flak under alle vindforhold, men lidt højere i medvind i forhold til modvind. Mønstrene af flyvehøjder for traner svarer i store træk til dem, der blev registreret for rovfugle, men en større andel af tranerne passerer Kriegers Flak ved højder over 200 meter. Den generelle nedstigning i flyvehøjde fra den svenske kyst i efteråret er ikke desto mindre meget klar. I løbet af foråret, ankommer de fleste traner til Danmark og Sverige på højde mellem 150 og 200 meter. I løbet af efteråret blev der registreret stejle nedstigninger af traner fra den svenske kyst i både medvind og modvind, nedstigningen var dog lidt stejlere i modvind. I gennemsnit ser fuglene ud til at krydse Arkona Basin ved lavere højde under medvind end modvind om efteråret. Ifølge fugletrækmodellernes forudsigelser flyver tranerne i gennemsnit i rotor højde af 10 MW møller, men lidt over 3 MW møllerne i alle vindforhold.

Den eksisterende viden om forekomsten af migrerende flagermus i Østersøen er meget begrænset, og formålet med forundersøgelsen var først og fremmest at registrere de arter, der typisk findes i området omkring Kriegers Flak. To flagermusdetektorer (Wildlife Acousticks SM2) blev installeret ved FINO 2 forskningsplatform mellem august og november 2013. Nathusius Pipistrelle blev registreret i højere tal på Kriegers Flak end andre arter af flagermus. Især den 11. september, hvor der blev gjort 215 registreringer af flagermus. Denne registrering viste, at større trækbevægelser som vi ser det hos landfugle kan finde sted for denne art offshore. Denne art har den største trækafstand mellem sommer-og vinterkvarter blandt de nordiske flagermus, og betragtes som en langdistance trækker. Artens hovedtrækretning er sydvest. Desuden blev brunflagermus, skimmelflagermus og sydflagermus registreret.

Den rumlige skala for habitatfortrængning af havlitter fra Kriegers Flak Havmøllepark er sammenlignelig med skalaen for fortrængning på grund af forstyrrelse fra anlægsfartøjer, dvs. 3 km. Derfor vil habitatfortrængning være den samme (302 km^2) under anlæg og drift af mølleparken, og det årlige antal af fortrængte fugle på samme niveau. Mellem 160 og 1300 havlitter vurderes at blive fortrængt årligt. Da driftsperioden kan vare 20 år eller mere, vil den samlede effekt af habitatfortrængningen under driften være større (moderat effekt) end under opførelsen, selv om det berørte antal havlitter svarer til mindre end 1 ‰ af den samlede bestand der overvintrer i Østersøen, og derfor er ubetydelig på populationsniveau. Effekterne af anlægget af eksportkablet til Rødvig på vandfugle vurderes at være ubetydelige.

Estimater for antallet af kollisioner med trækkende rovfugle og traner blev beregnet ved hjælp af en modificeret version af Band 2012 modellen baseret på en enkelt bevægelse af samme individ. Modellen blev anvendt for 10 MW møller (forventet worst case) for rovfuglearter og for 10 MW, 8 MW, 6 MW, 4 MW og 3 MW møller for traner. En dødelighed på 50% blev antaget for flokke, der kolliderer med møllerne. De følgende undvigelsesrater blev anvendt i kollisionsmodellerne; -0,24 (tiltrækning) for rovfugle ved brug af data fra Rødsand 2 havmøllepark og 0,69 for traner ved brug af data indsamlet under en dedikeret undersøgelse ved Baltic 2 vindmølleparken på den tyske del af Kriegers Flak i foråret 2015. Den dedikerede undersøgelse blev foretaget fra FINO 2 platformen ved hjælp af sporing af traner med en kombination af radar og laserkikkert. Undersøgelsen viste meget lave niveauer af makroundvigelse (tæt på nul), eftersom tranerne blev observeret uden tøven at flyve ind i vindmølleparken. Moderat vandret og lodret mesoundvigelse blev registreret hos tranerne inde i mølleparken.

Betydningen af de estimerede kollissionsrater blev vurderet ud fra de berørte bestandes (rovfugle og traner) evne til at kompensere det givne tab af individer. Dette blev gjort ved hjælp af tærskelværdier for bæredygtig reduktion i antallet af individer fra de relevante biogeografiske fuglebestande efter den såkaldte PBR (Potential Biological Removal) metode.

Kollisionspåvirkningerne blev for alle rovfugle og traner vurderet som små ved Kriegers Flak projektet, og ligeledes for Kriegers Flak projektet sammen med de eksisterende mølleparker Baltic 1 og Baltic 2. Det estimerede antal kollisioner blev for tranen estimeret til mellem 216 og 296 (afhængig af mølletype) for Kriegers Flak alene og mellem 366 og 446 for Kriegers Flak i kombination med Baltic 1 og Baltic 2.

Det skal understreges, at disse skøn hviler på to antagelser, som hvis forkerte kan forårsage antallet af kollisioner til at øges over PBR tærsklen. Det blev antaget, at tranerne både under forårs- og efterårs-trækket spredes over Arkona bassinet. På trods af at Kriegers Flak er placeret centralt på ruten mellem det sydlige Sverige og Rügen vil området ikke have en højere tæthed af flyvende traner end andre dele af regionen. For det andet er PBR tærsklen blevet etableret under forudsætning af ingen vigtig menneskeskabt dødelighed på bestanden. Vigtige kilder til dødelighed, som kan sænke PBR tærsklen ville omfatte kollisioner med den tyske Baltic 2 havmøllepark og elledninger. En forudsætning som må forventes at medvirke til en mere konservativ vurdering af kollisionsrisikoen er, at tranerne undvigelsesadfærd i Baltic 2 havmølleparken i forbindelse med adfærdsstudiet i foråret 2015 måske ikke var typisk. Idet havmølleparken ikke var færdigbygget og fuldt operationel (turbiner ikke installerede i 3 sydligste møllerækker, resterende møller i tomgang) er det ikke usandsynligt, at tranernes udviste mindre undvigelsesadfærd sammenlignet med en situation hvor mølleparken kører normalt.

Et stort antal dykænder anvender regionen undervejs mellem overvintringsområderne i de indre danske farvande og Nordsøen og ynglepladserne. Selvom vandfugletrækkets fordeling ikke er kortlagt i detaljer er det mest sandsynligt, at vandfugletrækket sker over en bred front med svage tendenser til koncentrationer langs kysterne af Sverige og Tyskland. Da vindmølleparken vil spænde omkring 13% af bredden af Arkona Bassinet vurderes barriereeffekten på migrerende vandfugle at være lille.

Kun mindre forstyrrende effekter på trækkende flagermus fra skibe forventes i løbet af byggeriet af mølleparken, men under driften kan kollisionsrisici ikke undgås. Selv om kollisioner mellem flagermus og havmølleparker endnu ikke er blevet dokumenteret, kan migrerende flagermus tiltrækkes af møllevingerne og tårne, hvis og når insekter samles der. Således vurderes kollisionsrisikoen for trækkende flagermus som lav til moderat.

I alt 12 vindmølleparker er planlagt eller godkendte i regionen omkring Kriegers Flak . Hvis de fire godkendte projekter i Tyskland bygges sammen med Kriegers Flak vurderes dette at medføre en moderat kollisionseffekt på traner, idet det årlige antal kollisioner estimeres at blive på mellem 1,112 og 1,192 fugle eller 60% af PBR tærsklen for en stabil bestand. Hvis alle projekter gennemføres sammen med Kriegers Flak og Bornholm vil de samlede kollisionseffekter på traner blive betydelige. Samlet set vurderes en kumulativ årlige kollisionseffekt på tranebestanden på mellem 2,620 og 2,700 fugle, eller på niveau med PBR-tærsklen for en stigende bestand. Dette kan medføre en øget dødelighed, som kan have længerevarende negative virkninger på den svensk-norske ynglebestand. I et sådant tilfælde kan en signifikant kumulativ effekt på fuglebeskyttelsesområder, der er klassificeret i henhold til EF Fugledirektivet for traner fra den svensk-norske bestand, ikke afvises. Dette vil være tilfældet også selvom kun de godkendte projekter gennemføres samen med Kriegers Flak, idet tranebestanden reguleres af flere dødelighedsfaktorer, som der ikke er taget højde for ved beregningen af PBR-tærsklen. Selvom der ikke er indikation for forventede betydelige virkninger (LSE) fra Kriegers Flak havmøllepark alene eller med de eksisterende Baltic 1 og 2 havmølleparker, kan en negativ bestandseffekt som følge af den kombinerede kollisionsrisiko associerede med driften af Kriegers Flak, Baltic 1, Baltic 2 og fire andre havmølleparker med byggetilladelse i Arkona regionen ikke udelukkes. Den samme konklusion gælder med hensyn til den kombinerede kollisionsrisiko med de øvrige 8 planlagte havmølleparker i regionen.

3 Introduction

In 1998 the Ministry of Environment and Energy empowered the Danish energy companies to build offshore wind farms of a total capacity of 750 MW, as part of fulfilling the national action plan for energy, Energy 21. One aim of the action plan, which was elaborated in the wake of Denmark’s commitment to the Kyoto agreement, is to increase the production of energy from wind power to 5.500 MW in the year 2030. Hereof 4.000 MW has to be produced in offshore wind farms.

In the years 2002-2003 the two first wind farms were established at Horns Rev west of Esbjerg and Rødsand south of Lolland, consisting of 80 and 72 wind turbines, respectively, and producing a total of 325,6 MW per year. In 2004 it was furthermore decided to construct two new wind farms in proximity of the two existing parks at Horns Rev and Rødsand. The two new parks, Horns rev 2 and Rødsand 2, are now producing 215 MW each and have been fully operational since 2010. The Anholt Offshore Wind Farm was constructed in 2012. It will produce 400 MW per year and constituted the next step of the fulfilment of the action plan, and it covers the yearly consumption of approximately 400.000 households.

The present report is one of a number of technical reports forming the base for the Environmental Impact Assessment for Kriegers Flak Offshore Wind Farm (Kriegers Flak OWF). The report describes the baseline investigations and impact assessment on birds and bats associated with the next large-scale offshore wind farm at Kriegers Flak. Energinet.dk on behalf of the Ministry of Climate and Energy is responsible for the construction of the electrical connection to the shore and for development of the wind farm site, including the environmental impact assessment. NIRAS with DHI and other sub consultants are undertaking the full-scale Environmental Impact Assessment for the wind farm.

3.1 Focus of the baseline investigation and impact assessment

The Project Area for the Kriegers Flak OWF is located in the central part of the Arkona Basin. The turbines will be constructed on the shallow sandbank Kriegers Flak, which shares characteristics with other shallow offshore banks in the western Baltic in terms of a relatively high biomass of blue mussels. The blue mussel community supports relatively high densities of mussel-feeding seaducks.

In addition, the Project Area is located midway between Sweden and Germany in a region which is considered strategically important for landbird migration, here especially raptors and Common Crane, which are sensitive to collision due to their perceived behavioural response to offshore wind farms and small populations. Thus, the baseline investigations and impact assessment on wintering waterbirds focus on seaducks, whereas the investigations and assessment on bird migration mainly cover migration of raptors and Common Crane.

Factors which may affect birds include habitat displacement due to disturbance, barrier effects and collision risks. The impact assessment will combine existing knowledge of the sensitivity of the wide range of species to habitat displacement, barrier effects and collision risks, including a dedicated study of behavioural responses of Common Crane to the German Baltic 2 project, and largely follow the methods developed and applied during the assessments of the impact of the Horns Rev1, Horns Rev 2, Nysted, Rødsand 2 and Anholt offshore wind farms. In addition, the assessment will draw upon the experiences from the monitoring activities related to the construction and operation of the above mentioned wind farms.

4 Project description

4.1 Introduction

This chapter outlines the proposed technical aspects encompassed in the offshore-related development of the Kriegers Flak Offshore Wind Farm (OWF) which are relevant in relation to the assessment of potential impacts on birds and bats. The text is extracted from the full technical project description (Energinet.dk 2014).

4.2 Kriegers Flak - Site Location

The planned Kriegers Flak OWF (600 MW) is located app. 15 km east of the Danish coast in the southern part of the Baltic Sea close to the boundaries of the exclusive offshore economic zones (EEZ) of Sweden, Germany and Denmark (see Figure 1). At the neighbouring German territory an OWF Baltic 2 is currently under construction, while pre-investigations for an OWF have already been carried out at Swedish territory, however further construction is currently on standby.

The area delineated as pre-investigation area covers an area of app. 250 km^2, and encircles the bathymetric high called “Kriegers Flak” which is a shallow region of approximately 150 km^2. Central in the pre-investigation area an area (c. 28 km^2) is reserved for sand extraction with no permission for technical OWF components to be installed. Hence, wind turbines will be separated in an Eastern (110 km^2) and Western (69 km^2) wind farm. Allowing for 200 MW on the western part, and 400 MW on the eastern part. According to the permission given by the DEA, a 200 MW wind farm must use up to 44 km^2. Where the area is adjacent to the EEZ border between

Sweden and Denmark, and between Germany and Denmark, a safety zone of 500 meters will be established between the wind turbines on the Danish part of Kriegers Flak and the EEZ border.

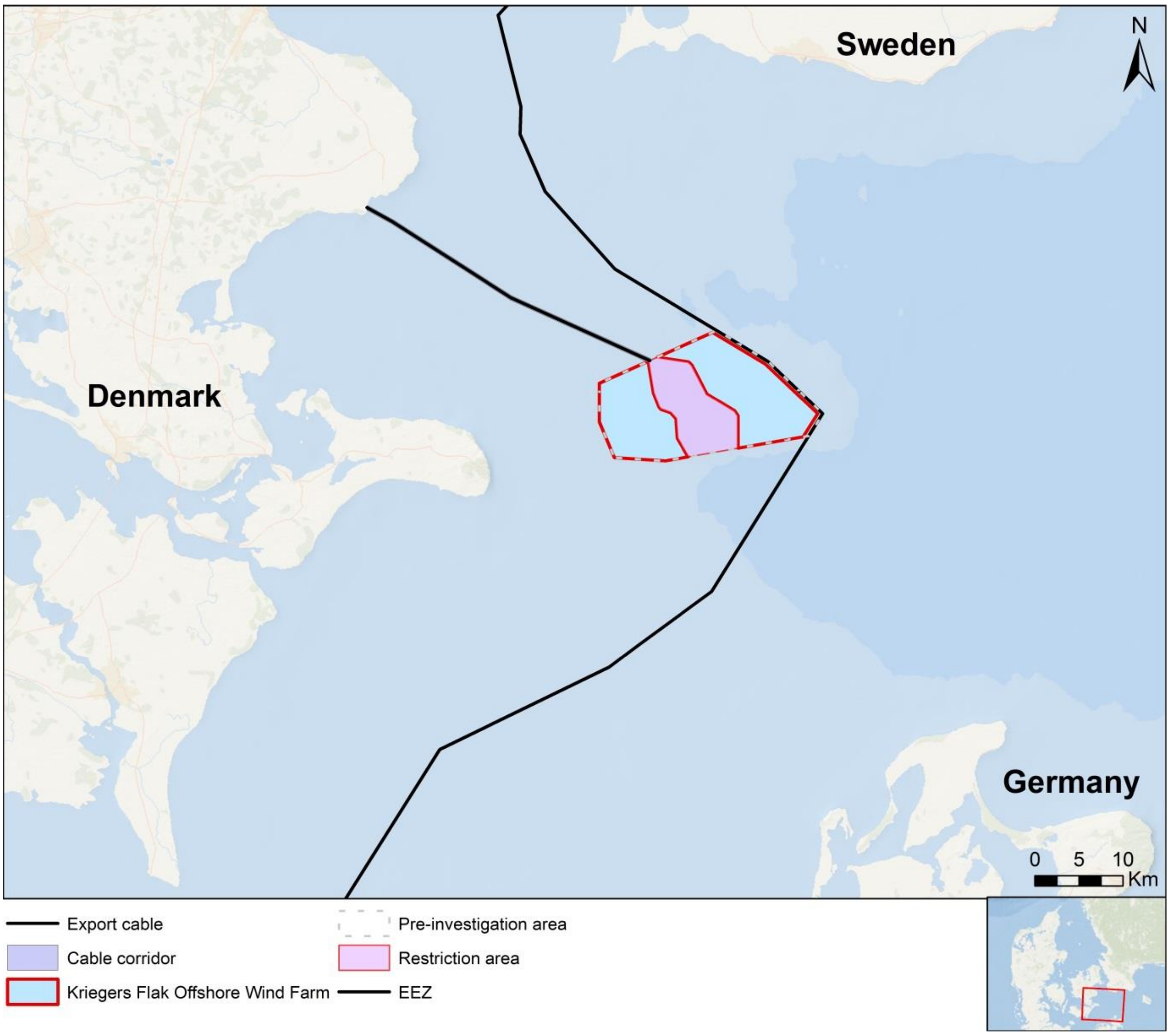


Figure 1. The planned location of Kriegers Flak Offshore Wind Farm (600 MW) in the Danish territory. Approximately in the middle of the pre-investigation area an area (c. 28 km2) is reserved for sand extraction with no permission for technical OWF components to be installed (red polygon).

4.3 **Physical Characteristics**

The water depth at the central parts of the Kriegers Flak is generally between 16 and 20 m, while it is between 20 and 25 m along the periphery of the bank, and more than 25-30 m deep waters along the northern, southern and western edges of the investigation area (Figure 2).

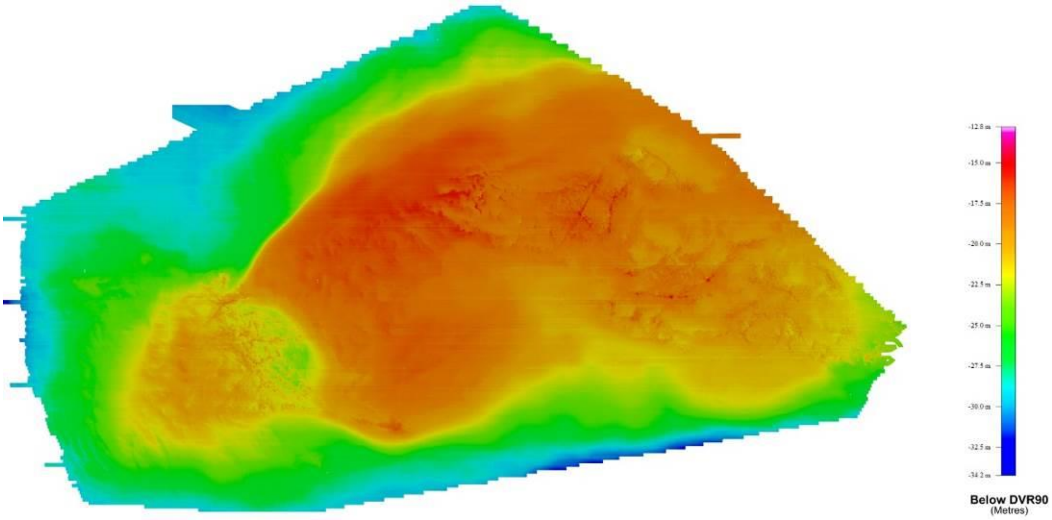


Figure 2. Overview of the Kriegers Flak area showing water depth variations by graded colour (based on the geophysical survey which was undertaken in 2012).

4.4 **Wind Farm Layout**

As input for the Environmental Impact Assessment (EIA), possible and likely layouts of the offshore wind farm at Kriegers Flak have been assessed and realistic scenarios are used in the EIA. It must be emphasized that the layouts may be altered by the signed developer. Possible park layouts with a 3.0 MW wind turbine (Figure 3) and a 10.0 MW wind turbine (Figure 4) can be seen below.

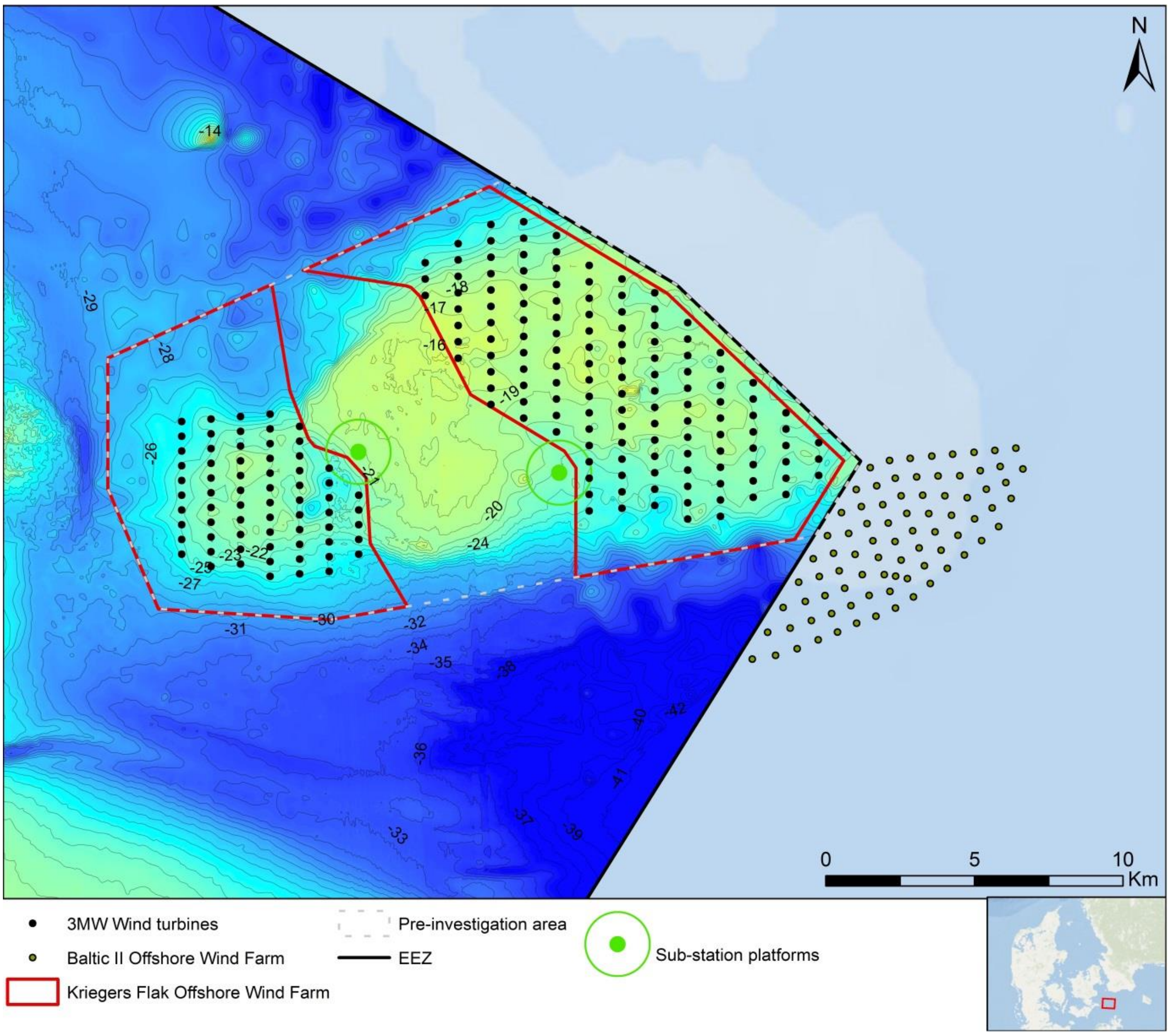


Figure 3. Suggested layout for 3.0 MW turbines at the eastern and western part of the planned wind farm (delineated by red polygons) at Kriegers Flak at Danish territory. The two green circles indicate the position of the offshore sub-station platforms. The broken line delineates the pre-investigation area. In the south-eastern part of the map turbines within the German Baltic 2 OWF are shown.

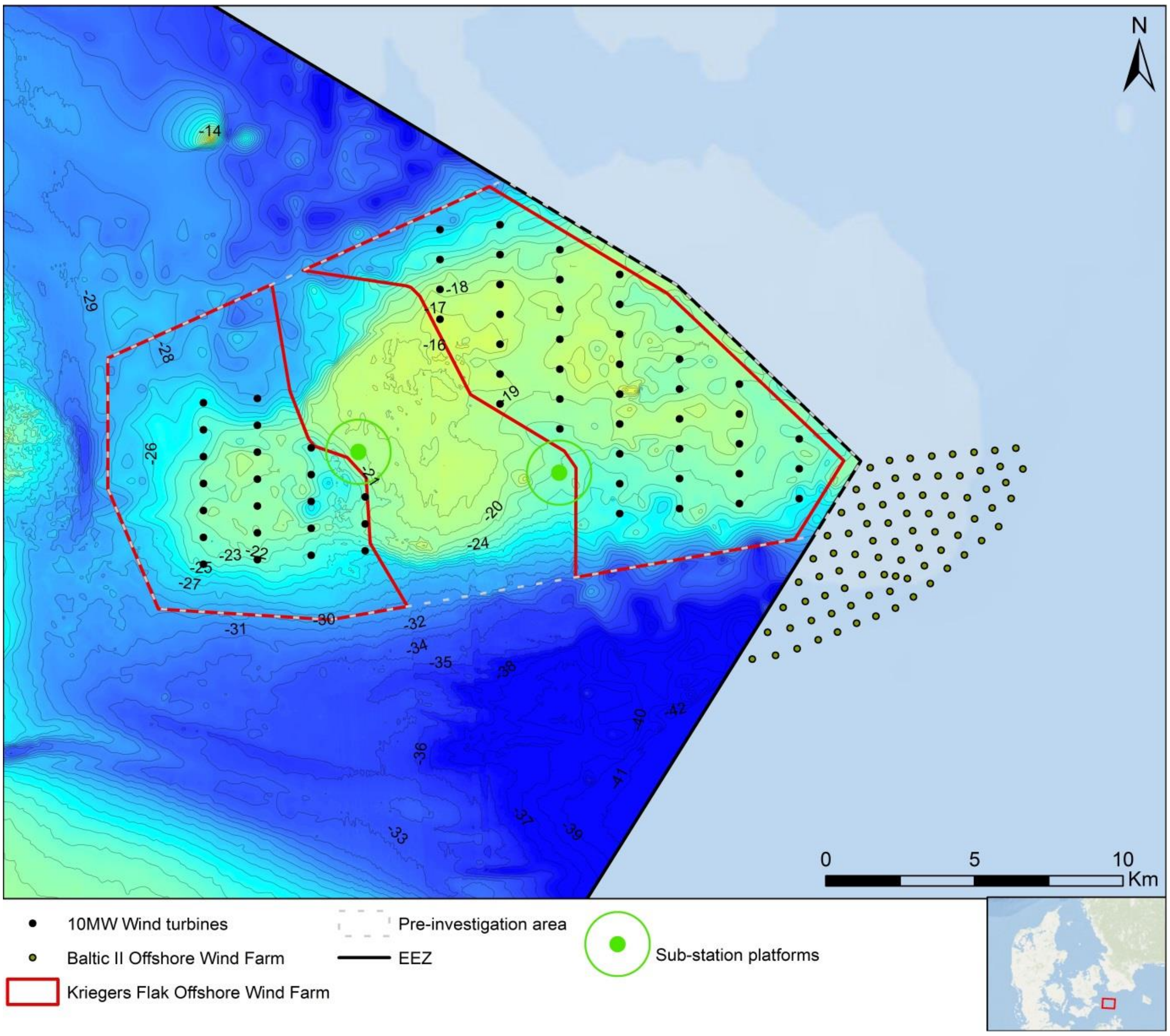


Figure 4. Suggested layout for 10.0 MW turbines at the eastern and western part of the planned wind farm (delineated by red polygons) at Kriegers Flak at Danish territory. The two green circles indicate the position of the offshore sub-station platforms. The broken line delineates the pre-investigation area. In the south-eastern part of the map turbines within the German Baltic 2 OWF are shown.

4.5 Wind turbines

4.5.1 Description

The installed capacity of the wind farm is limited to 600 MW. The range for turbines at Kriegers Flak is 3.0 to 10.0 MW. Based on the span of individual turbine capacity (from 3.0 MW to 10.0 MW) the farm will feature from 60 (+4 additional turbines) to 200 (+3 additional turbines) turbines. Extra turbines can be allowed (independent of the capacity of the turbine), in order to secure adequate production even in periods when one or two turbines are out of service due to repair. The exact design and appearance of the wind turbine will depend on the manufactures.

As part of this technical description, information has been gathered on the different turbines from different manufactures. It should be stated that it is the range that is important; other sizes and capacities from different manufactures can be established at Kriegers Flak, as long as it is within the range presented in this technical description.

The wind turbine comprises tubular towers and three blades attached to a nacelle housing containing the generator, gearbox and other operating equipment. Blades will turn clockwise, when viewed from the windward direction.

The wind turbines will begin generating power when the wind speed at hub height is between 3 and 5 m/s. The turbine power output increases with increasing wind speed and the wind turbines typically achieve their rated output at wind speeds between 12 and 14 m/s at hub height. The design of the turbines ensures safe operation, such that if the average wind speed exceeds 25 m/s to 30 m/s for extended periods, the turbines shut down automatically.

4.5.2 Dimensions

Preliminary dimensions of the turbines are not expected to exceed a maximum tip height of 230m above mean sea level for the largest turbine size (10 MW).

Outline properties of present day turbines are shown in Table 1 below.

*Table 1. Typical dimensions for offshore wind turbines between 3.0 MW and 10.0 MW. *MSL: Mean Sea Level.*

Turbine Capacity (MW)	**Rotor diameter (m)**	**Total height (m)**	**Hub height above MSL* (m)**	**Swept area (m^2)**
3.0MW	112m	137m	81m	9,852 m^2
3.6MW	120m	141.6m	81.6m	11,500m^2
4.0MW	130m	155m	90m	13,300m^2
6.0MW	154m	179m	102m	18,600 m^2
8.0MW	164m	189m	107m	21,124m^2
10.0 MW	190m	220m	125m	28,400 m^2

The air gap between Mean Sea Level (MSL) and wing tip will be determined based on the actual project. However, a minimum of approximately 20 metres above HAT (Highest Astronomical Tide) is expected as used for most Danish offshore wind farms. The Danish Maritime Authority (Søfartsstyrelsen) will need to approve the detailed design and distance between the HAT and lower wing tip before construction of the Kriegers Flak OWF.

4.5.3 Lighting and marking

The wind turbines will exhibit distinguishing markings visible for vessels and aircrafts in accordance with requirements by the Danish Maritime Authority and the Danish Transport Authority. Below is described the expected requirements for lights and markings.

Kriegers Flak will be marked on the appropriate aeronautical charts as requires by the Danish Transport Authority. It will also be lit in a way that meets the requirements of both aviation (civilian and military) and marine stakeholders. Lightning will be required to make the development visible to both aircrew and mariners. It is likely that two separate systems will be required to meet aviation standards and marine safety hazard marking requirements.

The light markings for aviation as well as the shipping and navigation will probably be required to work synchronously.

Final requirements in relation to lightning will be determined by the Danish Maritime Authority and the Danish Transport Authority when the layout and the height of the turbines are known.

4.6 Offshore sub-station platforms

4.6.1 Description

For the grid connection of the 600 MW offshore wind turbines on Kriegers Flak, two HVAC platforms will be installed. One (200 MW) on the western part of Kriegers Flak and one (400 MW) on the eastern part of Kriegers Flak. The planned locations of the platforms are shown on Figure 3 and Figure 4.

The platforms will be without any light when no people are aboard except from required navigational lanterns which will be flashing synchronously with the wind turbines, having an effective reach of at least 5 nautical miles corresponding to an intensity of approximately 75 candela.

4.7 Export cable

Two 220 kV export submarine cables will be installed from the offshore transformer stations to the landfall at Rødvig, in addition to the two export cables to shore, a 220 kV submarine cable will be installed between the platforms . The total length of the export cables will be approx. 100 km.

The Kriegers Flak area where the cables are to be installed is partly consisting of soft (sand) and hard (clay and chalk) sediments. It is expected that the export cables are installed in one length on the seabed and after trenching the cable is protected to the depth of one meter.

4.8 Wind farm decommissioning

The lifetime of the wind farm is expected to be around 25 years. It is expected that two years in advance of the expiry of the production time the developer shall submit a decommissioning plan. The method for decommissioning will follow best practice and the legislation at that time.

It is unknown at this stage how the wind farm may be decommissioned; this will have to be agreed with the competent authorities before the work is being initiated.

The following sections provide a description of the current intentions with respect to decommissioning, with the intention to review the statements over time as industry practices and regulatory controls evolve.

4.8.1 Extent of decommissioning

The objectives of the decommissioning process are to minimize both the short and long term effects on the environment whilst making the sea safe for others to navigate. Based on current available technology, it is anticipated that the following level of decommissioning on the wind farm will be performed:

1. Wind turbines – to be removed completely.
2. Structures and substructures – to be removed to the natural seabed level or to be partly left in situ.
3. Inter array cables – to be either removed (in the event they have become unburied) or to be left safely in situ, buried to below the natural seabed level or protected by rock-dump.
4. Scour protection – to be left in situ.

4.8.2 Decommissioning of wind turbines

The wind turbines would be dismantled using similar craft and methods as deployed during the construction phase. However the operations would be carried out in reverse order.

4.8.3 Decommissioning of offshore sub-station platform

The decommissioning of the offshore sub-station platforms is anticipated in the following sequence:

1. Disconnection of the wind turbines and associated hardware.
2. Removal of all fluids, substances on the platform, including oils, lubricants and gasses.

Removal of the sub-station from the foundation using a single lift and featuring a similar vessel to that used for construction. The foundation would be decommissioned according to the agreed method for that option.

5 Description of activities that could result in an impact on birds

The following description of activities that could result in an impact on birds has been based on all available documentation, especially results of post-construction monitoring at other offshore wind farms. Methods employed during the assessment of impacts on birds from the Kriegers Flak OWF are described in the Methods chapter (chapter 6).

5.1 Affecting factors during construction

Establishment of a marine wind farm covers a period of at least 12 months and is associated with a number of construction activities primarily including: traffic (vessels), pile driving, preparation of the seabed, sediment removal and deposition and cable laying. These activities result in a number of different impacts on the biological communities:

- Habitat displacement
- Habitat change

5.1.1 Habitat displacement

Habitat displacement effects on waterbirds during construction may vary as a function of the intensity of construction activities. Disturbance will probably be at the level seen during operation during intensive construction works, especially due to the concentration and movements of boats in the wind farm area. As the numbers of waterbirds using the area shows strong seasonal variability, the potential habitat displacement will depend on the timing of construction activities. As the abundance of most species of waterbirds at Kriegers Flak peaks during October-April the potential for habitat displacement impacts is largest during winter.

Waterbirds respond in different ways to approaching vessels. While some species are attracted to vessels as they expect food (gulls following fishing vessels) other species show a negative response and flush if a vessel approaches at a certain distance. The response differs not only between species but also in relation to the status of a species in its annual cycle, the function of the area and social structure of waterbird assemblages. Waterbirds are especially sensitive during moult where they show large disturbance distances, while reaction distances are smaller during the winter months (Thiel et al. 1992). Species like Common Scoter and divers exhibit large response distances of 1–2 km (Bellebaum et al. 2006, Schwemmer et al. 2011). The response distance usually increases with flock size making large aggregations more vulnerable to disturbance.

Of the species occurring in medium or higher densities in the construction site only Long-tailed Duck has been identified as being sensitive to disturbance. Based on the available information about planned dredger activities it is assumed, that these species will be displaced within the distances given in Table 2.

Table 2. Reported response of waterbirds to shipping (Bellebaum et al. 2006, Schwemmer et al. 2011).

Species	Response to shipping
Red-throated Diver (*Gavia stellata*)	1-2 km
Black-throated Diver (*Gavia arctica*)	1-2 km
Great Crested Grebe (*Podiceps cristatus*)	100-500 m
Red-necked Grebe (*Podiceps grisegena*)	100-500 m
Common Eider (*Somateria mollissima*)	100-500 m
Long-tailed Duck (*Clangula hyemalis*)	100-500 m
Common Scoter (*Melanitta nigra*)	1-2 km
Velvet Scoter (*Melanitta fusca*)	1-2 km
Razorbill (*Alca torda*)	100-500 m
Common Guillemot (*Uria aalge*)	100-500 m
Black Guillemot (*Cepphus grylle*)	100-500 m

5.1.2 Habitat impairment and destruction

The physical changes imposed by constructing the Kriegers Flak OWF include both direct and indirect impairment and destruction. A threshold of concentration of suspended sediment of 10 mg/l was considered as relevant in relation to direct negative response of feeding birds in the water column, although no evidence of behavioural responses of waterbirds to this threshold has been established.

5.2 Affecting factors during operation

By far the highest impacts on birds are associated with the operation phase due to the long-term duration of habitat displacement, barrier effect and collision risk impacts.

5.2.1 Habitat displacement

The evidence gathered from existing monitoring programmes at offshore wind farms indicate that specific responses of waterbirds to wind farms are highly variable, both as a function of specific disturbance stimuli and site-specific characteristics. In addition, adaptations to the turbines and rotor blades are observed, which make accurate assessment of the scale of habitat displacement rather difficult, especially over the long term. A further complication is the fact that habitat displacement impacts as documented during the monitoring programmes of existing OWFs may not have taken (natural) changes in food supply into consideration. Despite these uncertainties, habitat displacement is generally regarded as the main source of impact on birds from OWFs.

From Table 3 it can be seen that a pattern emerges in which species with offshore habitats display stronger reactions to OWFs than species with more coastal habitats. Species occurring widespread close to human developments, like gulls, are generally not disturbed by wind farms, while seabirds like divers and auks seem to be. Among the seaducks the more marine Common scoters and Long-tailed ducks have a higher potential for habitat displacement than the more coastal Eider. As experience is gathered at the increasing number of OWF sites habituation by several marine bird species to the structures becomes apparent. With the increasing number of monitoring activities a variance in specific responses by birds is observed, which may be accounted for by differences in site-specific characteristics as well as by variable levels of knowledge and data obtained. For example, aerial monitoring of birds around offshore wind farms in the United Kingdom are not allowed to survey the wind farm area at optimal altitude, and thus numbers of birds in the wind farm are generally missing from these reports.

Table 3. Reported response types of waterbirds and seabirds during OWF post-construction monitoring in relation to potential habitat displacement within a distance of 2 km from the wind farm.

Species	Site	Response type	Reference
Red-throated Diver (Gavia stellata)	Horns Rev 2	Complete avoidance of wind farm and reduction to 5-6 km distance	Petersen et al. 2014
	Horns Rev 1	Complete avoidance of wind farm area	Petersen et al. 2006b
	Nysted		Petersen et al. 2006b
	Kentish Flats, UK	Indication of habituation over time	Gill et al. 2008
	North Hoyle, UK	Indication of habituation over time	PMSS 2007
Black-throated Diver (Gavia arctica)	Horns Rev 1	Complete avoidance	Petersen et al. 2006b
	Nysted		Petersen et al. 2006b
Fulmar (Fulmar glacialis)	North Hoyle, UK	Indication of complete avoidance	PMSS 2007
Cormorant (Phalacrocorax carbo)	PAWP, NRL	Attraction	Leopold et al. 2012
	Nysted	No avoidance	Petersen et al. 2006
	North Hoyle	No avoidance	PMSS 2007
Gannet (Morus bassanus)	PAWP, NRL	Partiel avoidance	Leopold et al. 2012
	Horns Rev 1	Complete avoidance	Petersen et al. 2006b
	North Hoyle	Indication of no avoidance	PMSS 2007
Common Eider (Somateria mollissima)	Nysted	No or moderate displacement	Petersen et al. 2006b
Long-tailed Duck (Clangula hyemalis)	Nysted	Complete avoidance	Petersen et al. 2006b
Common Scoter (Melanitta nigra)	Horns Rev 2	Partiel avoidance and reduction to 2-3 km distance	Skov et al. 2012, Petersen et al. 2014
	Horns Rev 1	Initial moderate to complete avoidance of wind farm area followed by habituation	Petersen et al. 2006b
	North Hoyle	Indication of Habituation	PMSS 2007
Little Gull (Larus minutus)	Horns Rev 1	Indication of no avoidance	Petersen et al. 2006b
Herring Gull (Larus argentatus)	Nysted	No significant avoidance or attraction	Petersen et al. 2006b
	Horns Rev 1		
	Kentish Flats		Gill et al. 2008
		Indication of no avoidance	
Great Black-backed Gull (Larus marinus)	Kentish Flats	Indication of no avoidance	Gill et al. 2008
Kittiwake (Rissa tridactyla)	North Hoyle	No avoidance	PMSS 2007
Sandwich Tern (Sterna sandvicen-	Kentish Flats	Indication of no avoidance	Gill et al. 2008
	North Hoyle		PMSS 2007

Species	Site	Response type	Reference
sis)			
Common Tern (Sterna hirundo)	Kentish Flats North Hoyle	Indication of no avoidance Indication of no avoidance	Gill et al. 2008 PMSS 2007
Arctic/Common Terns (Sterna paradisaea/hirundo)	Horns Rev 1	Indication of moderate avoidance	Petersen et al. 2006b
Common Guillemot (Uria aalge)	PAWP, NRL Kentish Flats North Hoyle	Partiel avoidance Indication of avoidance Indication of no avoidance	Leopold et al. 2012 Gill et al. 2008 PMSS 2007
Razorbill (Alca torda)	PAWP, NRL Kentish Flats North Hoyle	Partiel avoidance Indication of avoidance Indication of no avoidance	Leopold et al. 2012 Gill et al. 2008 PMSS 2007
Common Guillemot/Razorbill (Uria aalge/Alca torda)	Horns Rev 1	Indication of avoidance	Petersen et al. 2006b

Despite the documented reductions in densities of some of these species following construction of offshore wind farms it should be pointed out that the reported numbers displaced so far are relatively small in comparison to total population levels, and hence bear no significance to the overall populations.

5.2.2 Habitat impairment and destruction

The presence of the Kriegers Flak OWF may affect bird habitats directly by either reducing the available area by its physical presence and by increasing available food supplies through creation of artificial reefs at the foundations of the turbines. Additionally, the turbines may serve as platforms for resting and perching birds, thereby attracting birds to the area that would not have exploited it previously.

5.2.3 Artificial reef effect

The bird species recorded to use the turbines as resting or perching platforms mainly include Cormorants and large gull species. However, in general the number of records of resting or perching birds associated with OWFs is very low compared to oil & gas installations, suggesting that the turbines do not represent attractive resting or perching platforms to birds.

5.2.4 Collision risk

Wherever wind turbines are erected birds will inevitably collide, due to the fact that flying birds and the rotor of turbines both utilise the lowest part of the atmosphere (Desholm 2006). However, the interesting question is in what numbers bird collide at a given wind farm. This can either be measured directly post-construction e.g. by corpse collection (at land-based wind farms) or by camera surveys (e.g. by thermal imaging at sea; Desholm et al. 2006). Or the collision numbers can be estimated through modelling on the basis of data on three dimensional flight/migration corridors in the vicinity of a proposed wind farm, known avoidance behaviour for the relevant species and size of the proportion of a given population that actually pass the proposed wind farm (Desholm 2006).

Birds can either collide directly with the physical structure of the turbines (i.e. rotor blade or tower) or get hit by the wake (i.e. turbulence) behind the sweeping rotor-blades. Thus, why do the birds not simply avoid flying in to the risk zone of the turbines/wind farm, and avoid a collision? Recent studies have shown that in practise most birds do actually avoid being hit by turbine rotor blades by simply showing evasive behaviour towards these man-made structures (Desholm & Kahlert 2005). However, situations occur where the flying birds cannot see the turbines, i.e. in situations with poor visibility (e.g. at night, in fog or during heavy precipitation) or if the birds are busy by looking for something else than obstacles in front of them (e.g. birds hunting for prey or looking for food, birds simply just following the flock mate in front of them, or birds chasing each other during territorial fights). Furthermore, birds may simply not perceive wind turbines as threats and then allow themselves to fly at very close range to sweeping rotor blades (e.g. White-tailed Eagles on the Norwegian island Smøla; Bevanger 2009).

However, the mortality rate at different wind farms is far from uniform, since local topography, bird numbers, species composition, wind turbine and wind farm design and local weather pattern can influence the actual number of birds colliding at a given site. The mortality rate is likely to be directly proportional to the migration volume, which again shows high variability between sites, seasons, individual turbines and weather conditions. Especially sites at migration bottlenecks, also known as migration hot-spots, are prone to experience very high concentrations of flying birds in the airspace occupied by the rotating blades of the turbines, and hence, also potential high wind farm related mortality rates (Desholm 2006). Traditionally, landbird migration hot-spots are characterized as landmass reaching out into the sea, however, in the present autumn study of migrating Common Crane it is the opposite situation, here Common Crane are leaving in a broad fronted manner at the coast of southern Sweden and are more or less all heading for a particular staging area at Rügen, Germany. This attraction situation also have the possibility of concentrating the migrating Common Crane and more so the closer they are to the staging area at Rügen.

At the species level, a given number of collisions at a wind farm may have very different direct effects on the population of these species, due to the species specific differences in sensitivities of this human induced additional direct mortalities (Desholm 2009). Most often large long-lived species (e.g. raptors, storks and Common Crane) show higher sensitivity than smaller and more reproductive bird species (e.g. passerines).

5.2.5 **Barrier effect**

To date, most avian studies of offshore wind power generation have either been focussing on collision mortality of flying birds or habitat displacement of staging birds (Petersen et al. 2006b). Nevertheless, since the often long migration journeys performed by many birds are rather costly in terms of energetic costs, any avoidance behaviour resulting in extra distance travelled, as a consequence of birds adjusting their flight paths in the presence of the wind farm, have the potential of having a significant additional energetic cost. However, only very few studies have dealt with this, for many considered as rather trivial, issue.

A barrier effect exists if birds which intend to fly through a channel or strait of open water as part of a long-distance migration, or movements related to resting and feeding are partly or entirely hindered by ships, wind farms or other obstacles to do so, resulting in a change of migration or flight routes and altitudes and thus in energetic costs to the birds.

Although monitoring at the established offshore wind farms have only partly involved combined visual and radar-based observations of behavioural responses of migrating birds to the structures experiences of species-specific responses have been gathered. Due to the Danish demonstration projects a large amount of information is available on the behavioural responses of migrating waterbirds to offshore wind farms. Waterbirds reacted to the wind farms at Horns Rev 1 and Nysted at distances of 5 km from the turbines, and generally deflected at the wind farm at a distance of 3 km. Within a range of 1-2 km more than 50% of birds heading for the wind farm avoided passing within it. At the Rønland offshore wind farm 4.5% of all waterbird flocks entered a zone of 100 m from the wind farm. At the Utgrunden wind farm in Kalmar Sund low-flying flocks of eiders were rarely seen to pass within 500m of the wind turbines during daytime, and avoidance behaviour was observed, with some birds altering direction 3-4 kms before reaching the Utgrunden wind farm to fly around it.

At the Nysted wind farm waterbirds entering the wind farm minimised their risk of collision by re-orientating to fly down between turbine rows, frequently equidistance between turbines and by reducing their flight altitude below rotor height and by readjusting flight orientation once within the wind farm to take the shortest exit route.

6 Methods

6.1 GPS tracking of Common Crane

In the international perspective, the Common Crane is the most important species in relation to assessments of risk of collision at the Kriegers Flak OWF, as the majority if not the entire Swedish and Norwegian populations pass the Arkona Basin on the route between breeding areas and staging areas in northern Germany (Swedish University of Agricultural Sciences Pers. Comm.). However, the risk of collision depends on the altitude of Common Crane migration and possible avoidance behaviour.

In order to estimate the flight altitudes in the offshore parts of this region satellite telemetry was applied by tagging 13 juvenile Common Crane at breeding sites in Sweden during summer 2013: 5 juveniles were tagged in Grimsö area and 8 in Tranemo (Figure 5). Nearly fully grown Common Crane juveniles were caught shortly before they are able to fly and transmitters were attached using flexible harness (Figure 6). The Common Crane were tagged with GPS / GSM transmitters powered by solar panels, which could provide precise positions and height measurements as the birds were crossing the Arkona Basin during autumn migration 2013.

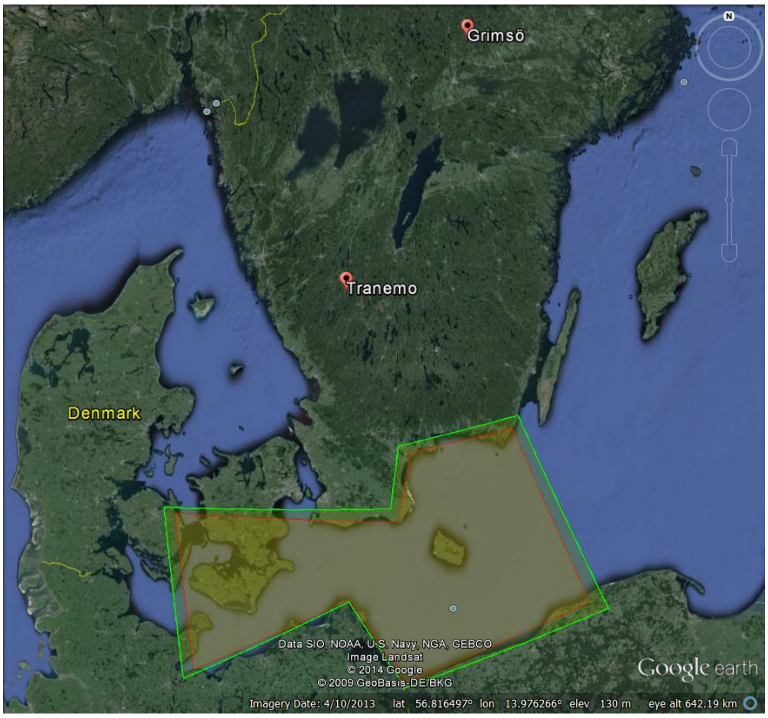


Figure 5. Locations of Tranemo and Grimsö in Sweden where Common Crane juveniles were caught and equipped with transmitters. The map also shows geo-fenced area where transmitters changed their duty cycle and started logging GPS positions every 30 seconds.

The tagging of Common Crane was undertaken in collaboration with the Swedish University of Agricultural Sciences and Tranemo Common Crane Study Group. The transmitters were programmed to collect GPS data at 15-30 minute intervals during daylight hours. But when over the Baltic Sea the tags were programmed to log GPS positions every 30 seconds using geo-fencing technique. Geo-fencing means that a geographic polygon is preset in a transmitter, and once the first GPS location is logged inside that polygon, the transmitter duty cycle changes.

Figure 6. Just released Common Crane juveniles with transmitters on their backs.

Not all tagged birds delivered data of their migration over the Baltic Sea: one juvenile has died within a month from tagging, most likely being taken by a predator; one bird stopped transmitting in early October while still in Sweden (in Stora Mosse National Park), likely indicating mortality or transmitter loss; and two other transmitters failed due to technical reasons (one stopped logging GPS positions, and the battery completely discharged on another). The remaining 9 individuals were tracked during their southward migration. Unfortunately, two of these birds failed to record GPS data at high resolution when crossing the Baltic Sea and one recorded its path only partly. It is difficult to know the causes of these malfunctions as all transmitters changed their duty cycle into high frequency GPS recording once in the geo-fenced area. Perhaps transmitter became heavily covered by feathers or its placement on a bird shifted during the flight over the sea and GPS antenna did not pick up satellite signals. Nevertheless, very high resolution tracks of 6 Common Crane have been successfully recorded providing unique information about flight trajectories and altitudes as Common Crane cross large expanses of water in different meteorological conditions.

Before using in altitude modelling collected telemetry data underwent some basic filtering. Several GPS positions with clearly erroneous altitude measurements were filtered manually by removing ‘negative altitudes’ and also measurements that were clearly unrealistic considering the fine temporal resolution of the dataset, i.e. records showing clear spikes when having altitude plotted along time axis.

6.2 Radar tracking of bird migration

During autumn 2013 and spring 2015, radar tracking of individual species of raptors and Common Crane was carried out from the FINO 2 research platform in the German part of Kriegers Flak. The platform is located just southeast of the Danish Kriegers Flak OWF area (

Figure 7). The tracking in autumn 2013 was done using a high-performance solid state radar (SCANTER 5000) with enhanced capacity for tracking over long distances and suppression of sea clutter. Enhanced suppression of sea clutter was deemed necessary due to the exposed location, and long distance tracking was important to map the distribution of migrating Common Crane across the central Arkona Basin. Common Crane could be tracked to distances of 20 km and tracking distances for raptors was generally less than 10 km. The radar antenna was placed on top of a container on the northern side of the platform deck (Figure 8). Due to a mast on the platform deck the scanning of the radar was blanked to the south (Figure 9). In spring 2015, a behavioural study of the responses of Common Crane to the Baltic 2 offshore wind farm (ENBW) was undertaken using a surveillance radar (LAWR 25). The antenna was placed on top of the container located in the southwest corner of the platform, and the radar was blanked to the north.

The SCANTER 5000 hardware consists of a radar transceiver with control unit (Table 4). The use of solid state technology makes it possible to do free and flexible frequency selection over the full band (9.0-9.5 GHz) with superior frequency diversity performances with possibility of up to 16 sub bands provides for enhanced possibilities to filter sea clutter and rain from bird targets. The software consists of the ET2 Tracker and Doppler Enhanced processing software. For real-time tracking and geo-referencing of bird movements DHI’s BirdTracker software was used (see below).

BirdTracker was also used during the Common Crane study in spring 2015 when tracking was performed with the LAWR 25 radar. This type of radar has been used during a large number of bird migration studies in Europe as well as in Denmark. The radar covered approximately 10% of the migration corridor in the Arkona Basin. The data acquisition hardware has been developed by DHI and includes ancillary hardware linked to the systems, allowing 24 hour operation and remote control. A local network connection has been installed to facilitate remote control. Details of the radar are given in Table 4.

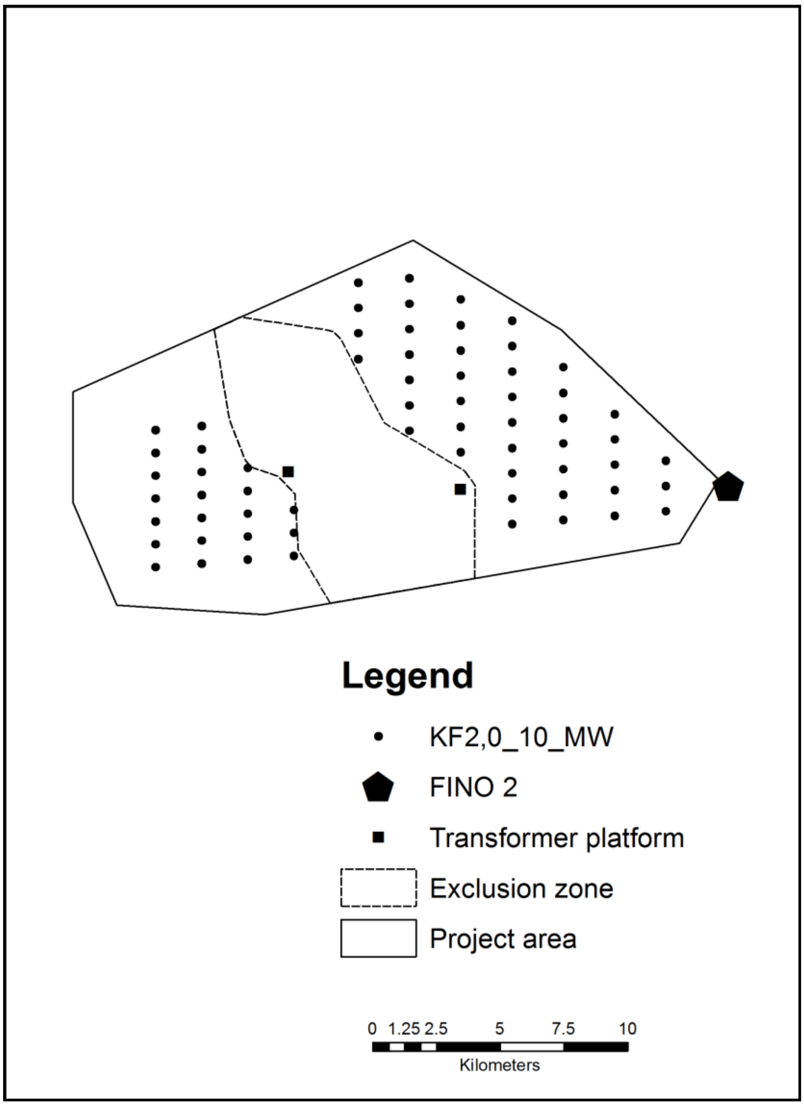


Figure 7. Location of the FINO 2 platform in relation to the Kriegers Flak project area and the 10 MW layout.

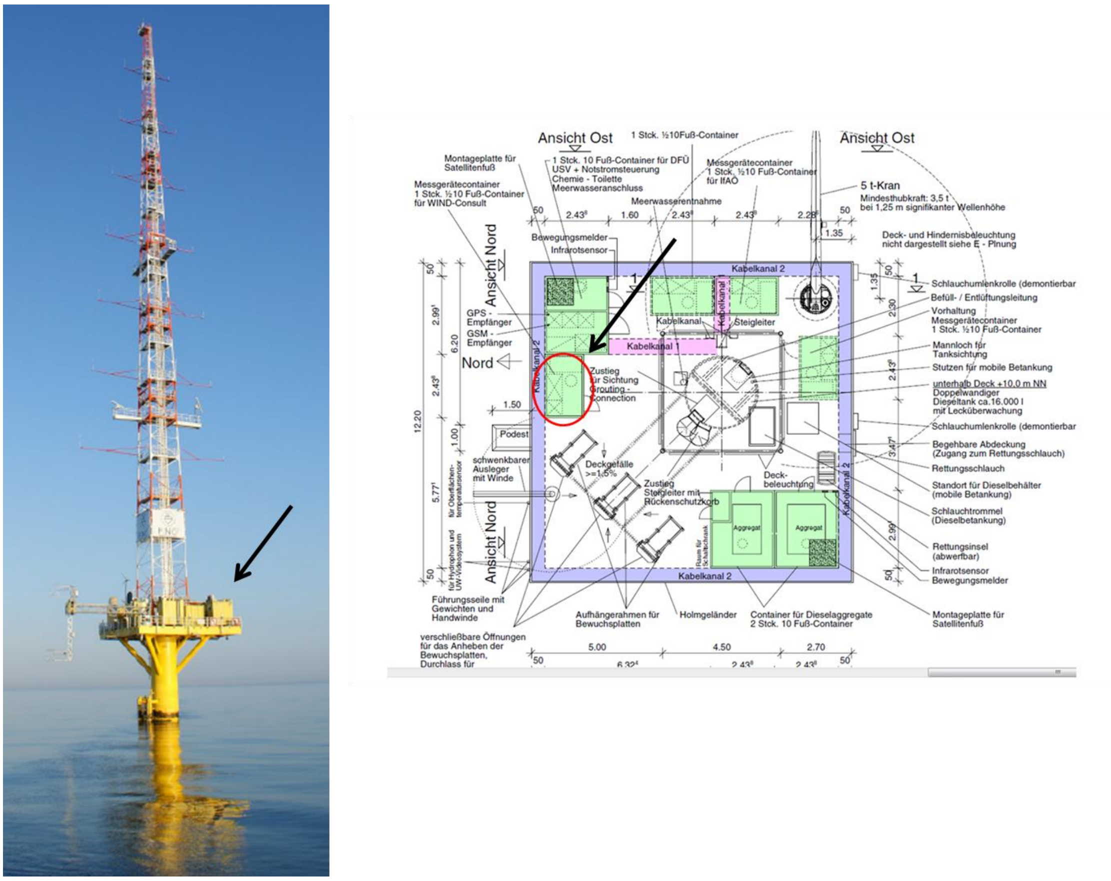


Figure 8. FINO 2 main deck, and placement of radar at 12 m altitude on the northern side of the platform.

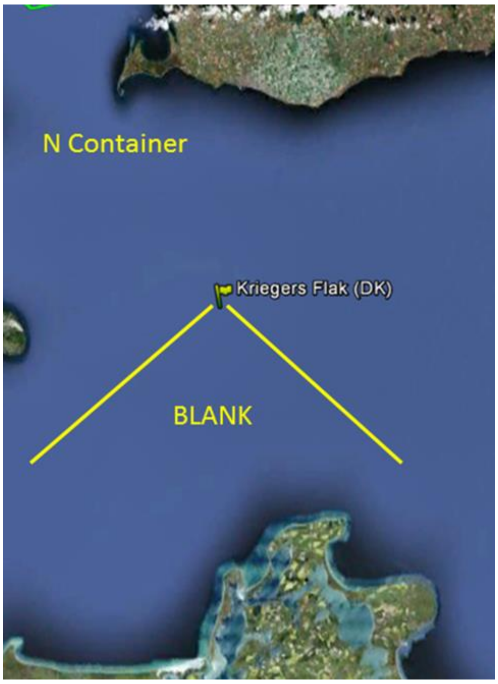


Figure 9. View of the radar blanked zone to the south.

Table 4. Specifications of the radar systems applied in the project.

Brand	SCANTER	LAWR 25
Type	SCANTER 5000	Furuno 2127
Power output	0-20kW programmable	25kW
Frequency	9.0-9.5 GHz programmable (16 sub bands)	9.4 GHz (X-band)
Range cell size	3 m	1.5 m
Rotational speed	60 rpm	24 rpm
Antenna length	3657 mm	2400 mm
Range	20 km	8 km

Using the horizontal radars, but adding species information was accomplished by a so-called “Real-time tracking” procedure, in which a dedicated software program "BirdTracker" makes it possible to draw/follow tracks of individual birds or flocks on background images, i.e. real-time videos from the radars. The videos are produced using a frame grabber connected to the surveillance radar and tailor-made software provides the video as a background image on the PC-screen with the radar position in the centre (Figure 10). During tracking the PC screen is divided into two parts, the radar video and the window to record data, including number of birds, flock altitude, flock size (dimension), behaviour, status when start tracking, status when end tracking, comments per track or per session; start and end time, number of nodes and coordinates per node are added automatically.

Two observers are involved in the real-time radar-tracking. One is following the tracks on the screen and is recording the information into a database. The second observer attempts to find the objects in the field, using binoculars and telescope, and provides species names, number of birds and estimates of flying altitude. Several tracks from the radars plus data can be recorded in parallel (at the same time) on the screen, one of them active at any given time. Each track has several nodes, representing the different locations of the track. In addition to the start and the end-point, directions are calculated automatically for all tracks.

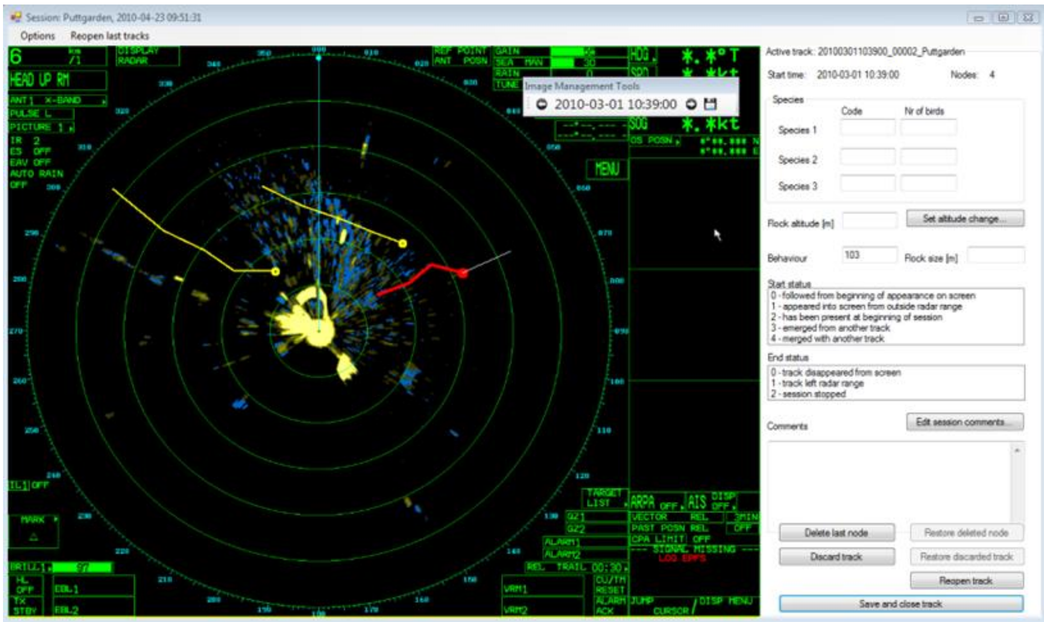


Figure 10. Screenshot of "BirdTracker" view with radar screen as background image on the left and editing sheet on the right. One active (red) and two inactive tracks (yellow) are shown from the same session. The white line on the right end of the active track indicates where to place the next node. Dots at one end of the track indicate the last active signal.

The purpose of the tracking session is to track and identify as many birds/flocks as possible. It is important to stress that the bird tracks identified may well constitute only a proportion of the total number of birds or bird flocks moving through the area investigated. This is a result of the sampling frequency combined with the number of bird tracks that is possible to identify by observers on the radar screen, which is an underestimation of the actual tracks. Also, during very busy situations it is not always possible to provide identifications for all tracks.

6.3 Rangefinder tracking of flight altitudes

Both during the baseline investigation during 2013 and the behavioural study of Common Crane in spring 2015, laser rangefinders (Vectronix 21 Aero®) were used to collect species-specific data on migrating birds both from the FINO 2 platform, from the Falsterbo Rev Lighthouse and from the coasts of eastern Denmark and southern Sweden.

The laser rangefinder is equipped with a build-in, battery driven laser system, that allows recordings of distance, altitude and direction to a given object. Thus operated at known geographical positions and elevations, the laser rangefinders can be used to obtain three-dimensional data on migrating birds. Under optimal conditions, laser rangefinders can be used out to a distance of between 2 and 3 km for the largest bird species, depending on the angle of view and on bird flight behaviour (gliding, soaring or flapping). Laser rangefinders can be operated or “fired” with approximately 10-15 sec. intervals and positions and altitudes logged automatically via GPS, and can provide long series of recordings for an individual focal bird or bird flock.

The metal constructions on the FINO platform and the Falsterbo light house causes distortion of the collected GPS-data by the rangefinder, which may interfere with the geo-positioning of the recorded rangefinder data. To account for this, calibration data was collected regularly by measuring the individual distances to three points in the vicinity of the platforms using the rangefinder. The calibration points were used to spatially adjust the location of records.

6.4 Other available data on bird migration

Baseline investigations undertaken in relation to the planned wind farms on the Swedish and German parts of Kriegers Flak and Adler Ground (Arkona Becken Südost, Ventotec Ost 2) have provided the main sources of recent information on the timing and intensity of bird migration through the Arkona Basin. The radar study by Petterson (2003) from the Swedish south coast provided spatial information about the migration of waterbirds through this sector of the Arkona Basin.

Recorded flight intensities of passerines during radar investigations in relation to planned wind farms provided information on the flux of landbirds, including nocturnal migration through the area (Kube et al. 2004b, IfAÖE 2003).

6.5 Available survey data on waterbird distribution

A recent review of wintering waterbird populations in the Baltic Sea based on co-ordinated censuses between 2007 and 2009 included the planned wind farm site on Kriegers Flak (Skov et al. 2011). Danish waterbird monitoring data from 2004 and 2008 (Petersen et al. 2006a, 2010) added further details on seaducks and less common species of waterbirds including Red-throated/Black-throated Diver and Black Guillemot. Baseline surveys undertaken in relation to the planned wind farms on the Swedish and German parts of Kiegers Flak added even more details on the use of the area by waterbirds (IfAÖ 2003, Kube et al. 2004a).

The review of waterbirds in the German EEZ by Garthe (2003) based on baseline surveys prior to development of marine wind farms supplemented details on regular occurrence of species of seabirds and seasonality on Kriegers Flak.

For three species of seaducks, Long-tailed Duck (*Clangula hyemalis*), Common Scoter (*Melanitta nigra*) and Velvet Scoter (*Melanitta fusca*) which occur in the region of the Arkona in concentrations of international importance ship and aerial based survey data from two different periods were used to create distribution models. For the first period, Period 1, we used data collected during 1987-1993 (described in Durinck et al. 1994). For the second period, Period 2, we used data collected during 2004-2009 (Skov et al. 2011). Distribution models for two different periods were necessary in order to assess possible changes in the importance of the Kriegers Flak area to watebirds on account of the large decline in abundance of seaducks seen in this part of the Baltic Sea since mid 1990es (Skov et al. 2011).

6.6 Acoustic detection of bats

The existing knowledge on the presence of migratory bats of the Baltic Sea is very limited, and the purpose of the study was primarily to record the species typically found in the region around Kriegers Flak. Two bat detectors were installed at the FINO 2 research platform between August and November 2013 (Figure 13). We used automatic units of type Wildlife Acousticks SM2 + with power adaptor and SMX-US Ultrasonic Microphone. Each bat detector can take 4x32 Gb. memory card. The detection distance depends on the species of bats and may vary from a few meters for species with weak sounds to approximately 50 m for species with stronger sounds.

Through Wildlife Acoustics software Kaleidoscope, data were extracted to wav format from the compressed wac format. Sounds below2 or above 30 milliseconds long and less than 14,000 Hz were filtered out. The remainder was stored for 5 seconds files and retained for analysis. Sounds representing bats were identified to species level using sonograms (see Figure 11 and Figure 12). Species determination was undertaken in collaboration with the Zoological Museum (Hans Baagøe), Copenhagen.

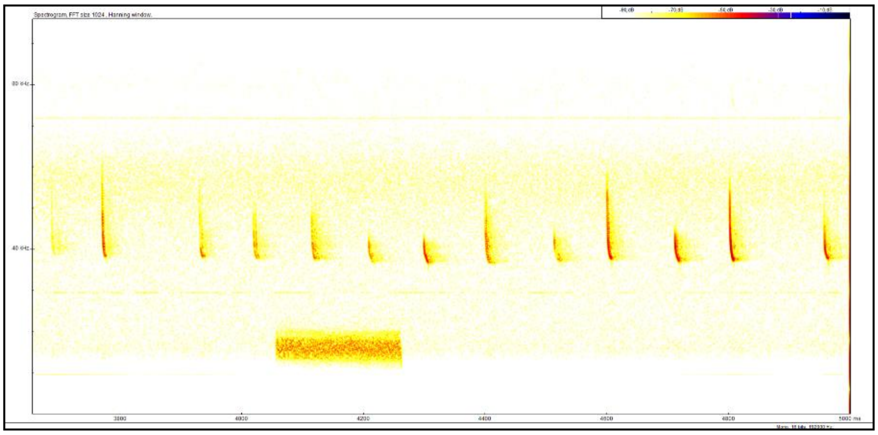


Figure 11. Example of a sonogram of Nathusius's Pipistrelle Bat.

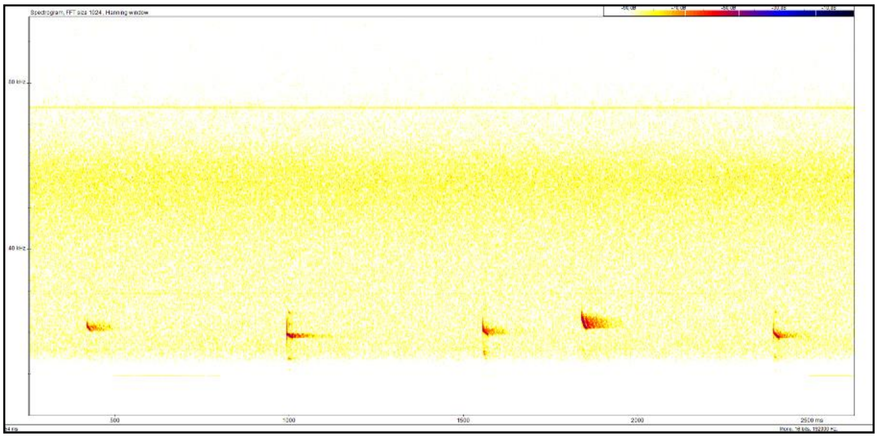


Figure 12. Example of a sonogram of Noctule Bat.

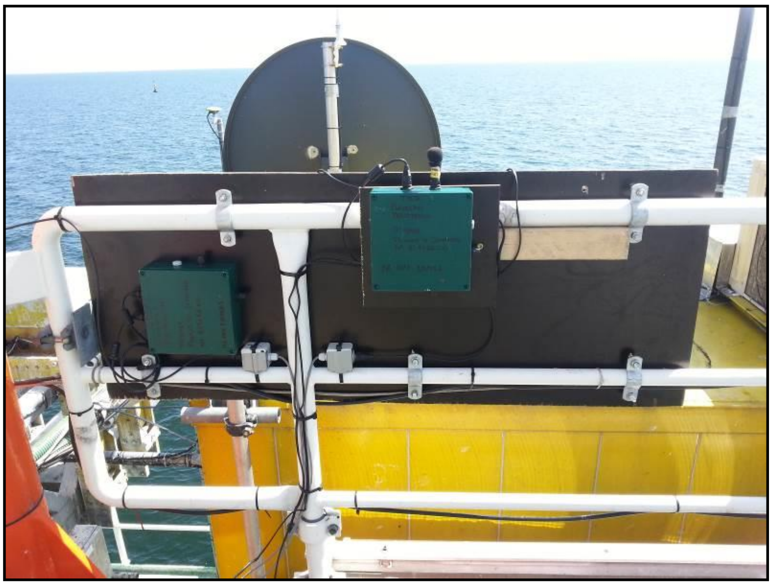


Figure 13. Installation of two bat detectors and microphone on FINO 2 platform.

6.7 Weather data

For the purpose of analysing the influence of weather conditions on the migratory behaviour of raptors and Common Crane modelled weather data from the regional model (WRF) by StormGeo were applied (www.storm.no). Modelled weather data were used in order to link obtained radar and rangefinder tracks at all locations to local weather conditions based on closest possible match in space and time. The regional weather model is based on the global weather model run by the European Centre for Medium-Range Weather Forecasts (UK). The spatial resolution of the WRF model is 0.1 x 0.1 degree, and the temporal resolution is one hour. Wind speed (m/s, at 10 m) and direction (as U and V wind components) as well as air pressure (hPa, at 10 m) were integrated with the radar and rangefinder track data. Clearness (% at 10 m, based on total cloudiness), relative humidity (% at 10 m) and air temperature (°C at 2 m) were additionally integrated with the track data. Clearness and humidity should here be seen as proxies for visibility (humidity inversely correlated with visibility).

In addition, historic wind measurements from Falsterbo were analysed to generate mean statistics for wind conditions in the region.

6.8 Data handling

6.8.1 Processing of radar and rangefinder track data

The data collected using rangefinder and radars were processed before used in the statistical analyses. Obvious outliers, wrongly located points within tracks, were removed by visually inspecting the tracks in ArcGIS 10.1. Rangefinder samples of Common Crane obviously influenced by thermals, i.e. birds approaching the coast in headwind and increasing greatly in altitude before reaching land were removed prior to the analysis. The rangefinder data also needed to be corrected for distortion due to the massive metal constructions of the FINO 2 platform. The corrections were made with the help of fixed calibration points (buoys) with known positions. The spatial corrections were made in ArcGIS 10.1 using the spatial adjustment tool (“similarity” method).

Weather data corresponding with time and position of the track data were extracted from model files. This was done using an integration tool made by DHI which is designed for extracting data from MIKE by DHI model files based on date, time and the coordinates. The integration by the tool is made by linear interpolation between the 1 hour time steps of the weather time series data. The wind components U (m/s in W-E direction) and V (m/s in S-N direction), air pressure, clearness, relative humidity, total precipitation and air temperature, all at 10 m:s altitude, were thus added as new columns to the track data files by using the integration tool. The U and V wind components were further converted to wind speed (m/s) and wind directions (0-360°). A correction factor of 1.41041532 was used for converting wind speeds at 10 m to wind speeds at 200 m to give a more realistic view of the actual wind speeds at a more commonly used migration altitude. A variable defining the flight direction in relation to wind direction was also created (Table 5). The variable defined in other words whether the bird was flying in head wind (within a range of 90 degrees), tail wind (within 90 degrees) or cross winds (within 90 degrees from either side).

All data collected by rangefinder on the south coast of Skåne were grouped together, as were the data collected by rangefinder from the Danish east coast (Sydvestpynten, Stevns Klint, Møns Klint).

Table 5. Wind directions used to define categories of head, tail and cross winds for raptors and Common Crane during spring and autumn 2013.

	Raptors spring	Raptors autumn	Common Crane spring	Common Cranes autumn
Tail wind	180°-270°	0°-90°	152°-242°	352°-51°
Head wind	0°-90°	180°-270°	332°-62°	141°-231°
Eastern cross wind	90°-180°	90°-180°	62°-152°	51°-141°
Western cross wind	270°-360°	270°-360°	242°-332°	231°-321°

6.9 Statistical analysis and modelling

6.9.1 Homogeneity of altitude slope

The rangefinder data were analysed to evaluate to what degree different tracks of raptors displayed similar or different trends in the response of migration altitude to the distance from the Swedish coast during autumn 2013. The tests of the homogeneity of slopes of different tracks were undertaken for selected species and wind directions using analyses of covariance (ANCOVA) in which distance to the Swedish coast was assigned as predictor variable and the species/wind direction was assigned as the categorical predictor variable. The results of the ANCOVA tests indicated the degree of similarity between tracks of different species and between tracks for selected species collected during different wind conditions. Significant interactions between distance and species/wind direction indicated different responses in flight altitude with distance between species.

6.9.2 Modelling flight altitudes

Statistical models were developed for the assessment of general patterns in the migration behaviour of Common Crane and raptors, regarding flight altitudes. These models are suitable for explaining the differences in flight altitude related to wind and weather conditions (wind speed, air pressure, relative humidity, clearness and temperature) and distance to land. Statistical models would potentially make it possible to generalise the flight patterns in order to improve the assessment of flight altitudes at Kriegers Flak during different weather conditions. If the flight altitude of raptors and Common Crane changes significantly with weather conditions the probability for collision will most likely also vary at the site, and the overall collision mortality will depend on the frequency of adverse conditions which cause the birds to fly at rotor height.

To be able to model the non-linear relationships (between the altitude and predictor variables), non-normally distributed errors and also account for the spatial and temporal autocorrelation (non-independencies in the residuals) in the data we used the semi-parametric and data driven generalized additive mixed modelling approach (GAMMs, Wood 2006, Zuur et al. 2009). Species-specific GAMMs with a suitable error distribution, either a Tweedie error distribution (with a log link and a power parameter between 1 and 2, Shono 2008) or a gamma distribution (with log a link) were fitted. To account for the temporal and spatial autocorrelation in the data we include the date (day and month) as a random term and a first order autocorrelation structure, corAR1, grouped by the individual tracks. The random effect and correlation structure were needed as one of the assumptions of the statistical method is that the samples (within the rangefinder, GPS telemetry or radar tracks) are independent of each other. This assumption is naturally violated as the succeeding samples in the various tracks are highly dependent on the previous samples.

We included distance to departure coast, clearness and humidity as smooth functions. For Common Crane and Common Buzzard wind speed was included as a smooth function and directions as a factor variable. For Sparrowhawk, Honey Buzzard, Red Kite and Marsh Harrier an interaction, a tensor product smoother, between distance to departure coast (with a thin plate regression spline) and wind direction (with a cyclic smoother) was included. The models were fitted using R version 2.13.0 (R Development Core Team, 2004) and the "mgcv" package (Wood, 2006).

The predictive accuracy of the models was evaluated by using a split sample approach, fitting the model on 70% of the tracks and evaluating the models on the remaining 30%. The agreement between the observed and predicted altitudes was tested using the Spearman's rank correlation coefficient. The model fit was also assessed by the adjusted R-square values (variance explained) and an inspection of the residuals.

We further used the models (based on all tracks) for predicting the average flight altitude at Kriegers Flak during average weather conditions (in the species specific data set) during tail, head and cross winds.

6.9.3 Modelling waterbird distribution

Predictive distribution modelling was applied for the most prevalent waterbird species in the seas surrounding Kriegers Flak, i.e. Long-tailed Duck, Common Scoter and Velvet Scoter. Distribution and abundance of waterbirds were assessed for two different time periods, as substantial changes in bird densities between mid-90s and more recent surveys (2008-2009) has been reported (Skov et al. 2011, Figure 14).

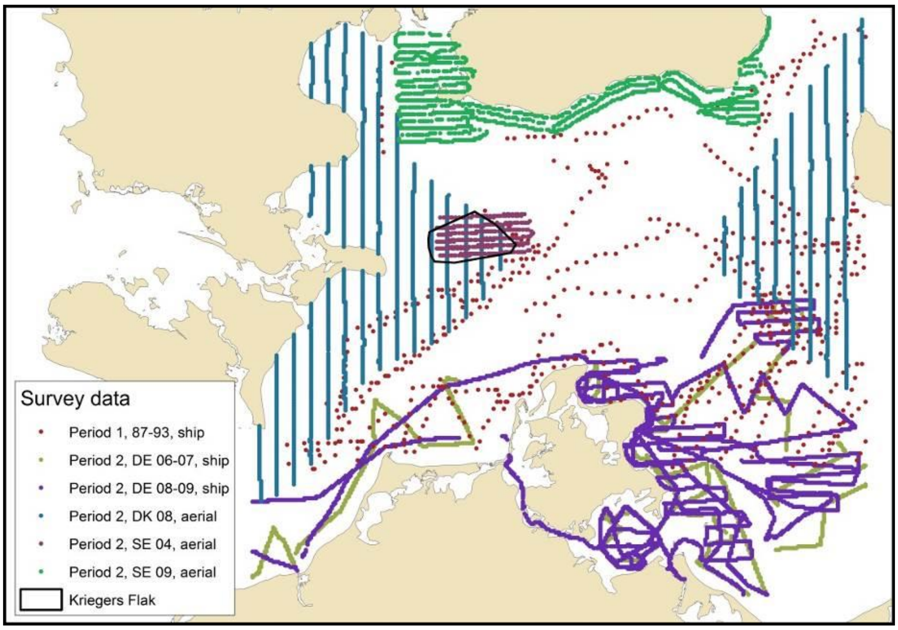


Figure 14. The survey data used in the distribution models. Both aerial and ship based survey data was used from two different periods.

We used a combination of available ship and aerial based survey data from two different periods to create the distribution models. For the first period, Period 1, we used data collected during 1987-1993 (described in Durinck et al. 1994). For the second period, Period 2, we used data collected during 2004-2009 (Leif Nilsson 2004 and Skov et al. 2011).

Following experience from modelling of waterbird distribution in other parts of the Baltic Sea, eight potentially important predictor (environmental) variables were included in this study; a filter feeder index (Skov et al. 2011), water depth (resampled DHI bathymetry raster), bottom slope (derived from depth), distance to land (Euclidean distance to coastline), AIS (index based on number of ships in each grid cell, Skov et al. 2011), distance to sand, distance to hard bottom and distance to mud. The distance layers to the bottom substrates were based on the "BALANCE sediment layer" (downloaded from http://www.helcom.fi/GIS/BalanceData/en_GB/main/). Distance to sand is the Euclidean distance to class III, distance to hard bottom is the distance to classes I and III and finally distance to mud is the distance to class V. AIS data on ship density representing a typical month (August 2010) was received from the Danish Maritime Authority.

The filter feeder index represents modelled filter-feeder carrying capacity, which describes the average carrying capacity using an arbitrary scale based on DHI's hydrodynamic and geo-biochemical model complex BANSAI 3. The carrying capacity is used as a proxy for biomass of mussels and combines a physiology-based growth model for a standard individual with an advection term that replenishes the food ingested by filter-feeders. On a large scale the index depends on the local primary production and on a smaller scale current speed plays an increasing role. Water depth and bottom slope are two parameters of the seabed which both typically have a relatively large influence on the distribution of benthivorous waterbirds. Distance to land and AIS data both reflect pressures in terms of disturbance from coastal development and ship traffic, and hence are expected to influence distribution of waterbirds negatively. Distance to sediment classes is often found to have a significant effect on the distribution of waterbirds, not least seaducks feeding on mussels growing on hard substrate or coarse sediments.

A semi-parametric two-step generalized additive model (GAM) was used to account for the zero inflation (a disproportionate large number of zeros) found in the survey data and the potential nonlinear relationships to the environmental variables (Stefansson 1996). As the first step a binomial (presence/absence) model was fitted. In the second step all zeros were removed and a gamma model (with a log link) was fitted with the densities of long-tailed ducks, common scoters and velvet scoters as the response variables and the environmental variables listed above as the predictor variables. The predictions from both parts of the models were combined (multiplied) to yield the final density predictions. The models were fitted using the "mgcv" R package. We defined the maximum degree of smoothing to 5 (k=5), to reduce the risk of overfitting the response curves. All variables were included in the model and non-influential variables were dropped, if any.

Model fit was assessed based on deviance explained and the predictive accuracy based on a split sample approach. We used 70% of the data for fitting the models and 30% for evaluation. The observed values in the evaluation data set were then assessed against the predicted (modelled based on the calibration set) using the Spearman correlation coefficient. All the data was used in the final model. We assessed also the model residuals for spatial autocorrelation using a Moran's I autocorrelogram (defining the nearest neighbourhood as 2500 m in the survey data from period 1 and as 1000 m in period 2, due to the different resolutions of the original survey data). When strong spatial autocorrelation was found in the model residuals we refitted the model as a generalized additive mixed model GAMM, which allows for inclusion of a correlation structure and thus is capable for dealing with the spatial autocorrelation. We used the first order "corAR1" autocorrelation structure for fitting the GAMM. The corAR1 correlation structure accounts for that the closest samples in time (thus also space in this case) are most correlates and the furthest a part the least correlated.

6.9.4 **Assessment of collision risks to migrating birds**

The collision model for landbirds on long-distance migration (Band et al. 2012) is based on the assumption of single transits of the same individual. The model has been widely applied to land-based and offshore wind farms in order to assess likely collision risks for migrating birds. The Band model provides predictions of the number of birds likely to be killed annually due to collisions with a specified type of rotor for a specified wind farm, and it is set up using a range of parameters relating to the flight behaviour and morphological details of the species and details of the design of the wind turbine. The largest source of uncertainty behind the model predictions is related to the avoidance rates displayed by the species towards wind farms. For several species, applied avoidance rates have now been validated using data from before-after studies (Cook et al. 2014). For the species in focus in this assessment of collision rates (raptors and Common Crane) no empirical data on collisions at offshore wind farms are available. The model was applied using bird crossings of the 10 MW layout (expected worst case) for raptor species and for the 10 MW, 8 MW, 6 MW, 4 MW and 3 MW layouts for Common Crane. Examples of the input parameters and results from the Band 2012 model are found in Appendix B. Initial collision models developed following baseline investigation in 2013 indicated potentially high risks for Common Crane. However, due to the lack of behavioural data on the response of migrating Common Crane to an offshore wind farm assessments of the actual collision risks involved were highly uncertain. It was therefore decided to undertake supplementary investigations in spring 2015 of Common Crane responses at the Baltic 2 offshore wind farm located close by in the German part of Kriegers Flak. The behavioural records from spring 2015 formed the basis for the assessment of collision risks for Common Crane. As estimates of the total numbers of raptors on long-distance migration crossing the Arkona Basin are not available, these numbers were estimated from historic statistics on raptor migration at Falsterbo (Karlsson et al. 2004) and migration directions sampled by laser rangefinder at Falsterbo during autumn 2013. The proportion of raptors crossing the Baltic Sea towards the central part of Arkona and Kriegers Flak was determined by the proportion of migration directions between 135° and 195°. Based on data from satellite tagging programs the entire Swedish and Norwegian populations of Common Crane are expected to cross the region (Agricultural University in Sweden Pers. Comm.). For all designs a productivity of 90% was applied.

The Band (2012) collision model is split into five stages:

"Stage A assemble data on the number of flights which, in the absence of birds being displaced or taking other avoiding action, or being attracted to the windfarm, are potentially at risk from windfarm turbines;

Stage B use that flight activity data to estimate the potential number of bird transits through rotors of the windfarm;

Stage C calculate the probability of collision during a single bird rotor transit;

Stage D multiply these to yield the potential collision mortality rate for the bird species in question, allowing for the proportion of time that turbines are not operational, assuming current bird use of the site and that no avoiding action is taken; and

Stage E allows for the proportion of birds likely to avoid the windfarm or its turbines, either because they have been displaced from the site or because they take evasive action; and allow for any attraction by birds to the windfarm e.g. in response to changing habitats. "

The collision estimates are thus derived by combining the 5 stages. Stage A defines flight activity of birds which is used in Stage B for estimating the "flux" of birds trough the rotors due to the passage rates. In stage C the probability of collision during a single transit is calculated based on the wind turbine and bird characteristics. Here, the proportion of up- and down-wind is also taken into account. The proportion was set to 50 % for both autumn and spring seasons based on the historic weather statistics from Falsterbo. vStage B and C are further combined in Stage C by multiplying the number of bird transits with the single transition collision risk and the proportion of time the windfarm is operating, which gives the number of collisions per month assuming no avoidance reactions. In Stage D the avoidance reactions are then further added and yield the final collision estimate per month. We have used an avoidance rate of -0.24 for raptors and 0.69 for Common Crane combining micro, meso and macro avoidance rates in the following way:

$$1 - ((1 - macro) \cdot (1 - meso) \cdot (1 - micro))$$

The avoidance rate of -0.24 for raptors is based on macro avoidance (attraction) rates of -0.35 recorded for migrating Honey Buzzard (*Pernis apivorus*) and Red Kite (*Milvus milvus*) at the Rødsand-2 wind farm in Denmark (based on Kahlert et al. 2011, Skov et al. 2012), and assuming a meso avoidance rate of 0 in the absence of data on this component and a micro avoidance rate 0.08 following Winkelmann (1992). The avoidance rate of 0.69 for Common Crane was based on the results of the dedicated behavioural study at the Baltic 2 offshore wind farm in spring 2015 where a macro avoidance rate of 0.07 and a meso avoidance rate of 0.64 were recorded. As for raptors a micro avoidance rate of 0.08 was assumed.

The Band collision model has been developed to estimate collisions of single flying birds, and does not take into account that for species which migrate in flocks, like Common Crane, it is likely that some individuals in the flock will respond during the event and avoid collision by aversive flight behaviour. In the absence of empirical data regarding the proportion of individuals in a flock likely to respond in a collision event we applied a factor of 50 % to the collision estimates for Common Crane, meaning that the number of birds dying from the collision would be half the total number estimated to collide if all individuals continued their flight path and crossed the rotor during the event.

The significance of the estimated collision rates at the Kriegers Flak OWF was assessed by comparison with the compensatory potential of affected populations of raptors and Common Crane. This was done using thresholds for sustainable removal from the relevant bio-geographic bird populations concerned. These assessments are conservative, and follow the so-called PBR (Potential Biological Removal) concept. The main advantage of this approach is that it relies on those demographic parameters which are easiest to obtain for the species.

The PBR approach is widely used to guide conservation and management of long-lived species like marine mammals (Wade 1998) and has been demonstrated as a useful tool to assess impacts of fisheries by-catch mortality on birds. The PBR is a threshold of additional annual mortality, which could be sustained by a population. PBR is a conservative metric and accounts for potential bias due to density dependence, uncertainty in estimates of the population size and stochasticity (Wade 1998; Taylor et al., 2000; Milner-Gulland & Akcakaya 2001). Additive mortality exceeding PBR would indicate potentially overexploited populations.

Recently, PBR has become increasingly used in studies analysing effects of additive mortality on waterbird populations (Niel & Lebreton 2005; Dillingham & Fletcher 2008). Bellebaum et al. (2010) calculated PBR for a number of bird species, including waders and passerines, aiming to assess thresholds of collisions with offshore wind parks in the German Baltic Sea that bird populations can sustain. However, the PBR concept has been developed and sufficiently tested only for birds with K-strategic life histories, i.e. long-lived and slow reproducing species like raptors and Common Crane.

PBR is calculated using the following general equation (Wade, 1998):

$$PBR = \frac{1}{2} R_{\max} N_{\min} f$$

where R_{max} is maximum recruitment rate, N_{min} is minimum population size, and f is recovery factor used to account for uncertainty in population growth rate and population size. Maximum recruitment rate is calculated considering maximum annual population growth rate:

$$R_{max} = \lambda_{max} - 1$$

where λ_{max} is maximum annual population growth rate, which is solved using the equation suggested by Niel & Lebreton (2005), which requires only adult bird annual survival probability (S_{ad}) and age of first reproduction (α):

$$\lambda_{\max} = \exp\left(\left(\alpha + \frac{S_{ad}}{\lambda_{\max} - S_{ad}}\right)^{-1}\right)$$

For minimum population size (N_{min}) Wade (1998) suggested using the lower bound of the 60% confidence interval of a given population estimate. However, a majority of available bird population estimates lack measures of uncertainty and provide either one figure for population estimate, or the upper and lower bound between which the actual population size is expected to lie. In the latter situation, the lower bound was used as an approximation representing N_{min}. If only one number was provided as population estimate, following Dillingham & Fletcher (2008) we estimated N_{min} as the 20th percentile of the population estimate assuming coefficient of variation $CV_{\bar{N}} = 0.05$.

The population recovery factor *f*, used to account for uncertainty in population growth rate and population size, ranges between 0.1 and 1. Dillingham & Fletcher (2008) suggested a recovery factor $f = 0.7$ for increasing populations, $f = 0.5$ for stable populations, $f = 0.3$ for declining, $f = 0.1$ for rapidly declining. These *f* values were accepted in our assessment, and we additionally used $f = 0.7$ for species with increasing population trend.

The estimates of the number of bird passing the study area in autumn were used as reference populations for the PBR. Obviously, the reference populations are much larger than the numbers passing the Arkona Basin, however by using the regional total numbers as reference points the calculated thresholds demonstrate the range of extra mortality which the regional and total populations may sustain.

Due to the focus on collisions risks for migrating Common Crane several thresholds were defined in order to inform the impact assessment in relation to this species. The PBR threshold for a stable population ($f = 0.5$) was estimated at 1,887 birds, while the threshold for an increasing population ($f = 0.7$) was assesses at 2,642 birds. The PBR threshold has been established in the absence of information on all potential anthropogenic sources of mortality of relevance to Common Crane. The Common Crane population in Sweden and Norway is regulated by a number of anthropogenic factors including habitat destruction, habitat changes due to climate change and collisions with power lines. Accordingly, the 100% thresholds were not used directly to guide the assessment. Instead 50 % of the PBR threshold for a stable population was used as a threshold below which significant impacts at population level can be discounted. 50 % of PBR then marked the threshold between minor and moderate impact, while values approaching 80 % of PBR or above marked the threshold between moderate and major impact. A stable population was used precautionary as a reference population in view of the most likely population development over the future 20 year period of wind energy production in the region.

6.9.5 Assessment of barrier effects on migrating birds

Barrier effects on movements and long-distance migration of seabirds resulting in a change of migration or flight routes and altitudes and thus in energetic costs to the birds have been well-described from existing offshore wind farms (Masden et al., 2009; Masden et al., 2010). Monitoring at existing offshore wind farms has involved combined visual and radar-based observations of behavioural responses of migrating birds to the turbine structures. Experiences related to species-specific responses in the Baltic Sea have been gathered at the Nysted wind farm. Waterbirds reacted at distances of 5 km from the turbines, and generally deflected at a distance of 3 km from the wind farm (Petersen et al., 2006b). Within a range of 1-2 km more than 50% of birds heading for the wind farm avoided passing within it. Waterbirds entering the wind farm minimised their risk of collision by re-orientating to fly down between turbine rows, frequently keeping equidistance between turbines and by reducing their flight altitude below rotor height and by readjusting flight orientation once within the wind farm to take the shortest exit route.

Studies at the Nysted and Horns Rev 1 wind farms have shown that the wind farm site is avoided and detoured to a greater extent by migratory waterbirds than by resident waterbirds (Blew et al., 2008). Seaduck species, particularly Common Scoter at Horns Rev and Common Eider at Nysted were registered in high numbers in the vicinity of the wind farms. Although, the seaducks were showing a general avoidance to enter the wind farm areas, individuals and groups of those species were found within the wind farm areas. Likewise, it has been found that scoters seem to exhibit avoidance behaviour of turbines in a Dutch offshore wind farm area (Leopold, et al., 2012). Extreme reactions such as turning back on encountering the wind farm were not observed. The avoidance of the offshore wind farms occurred by birds flying around it as well as above it (Blew et al., 2008).

In order to assess the degree and nature of barrier effect of waterbirds at Kriegers Flak OWF the specific avoidance distances reported from Nysted and Horns Rev will be applied to published data on the migration intensity of different species of waterbirds at the site.

6.9.6 Assessment of cumulative impacts and severity of impacts

The Kriegers Flak OWF will be developed in a region of currently moderate human activities, except for wind farm, fishing and resource extraction activities, which cause additional impacts on birds. Importantly, the German Baltic 1 and 2 wind farms have been erected next to the Danish project, and bird populations impacted by these wind farm have been considered as part of the baseline conditions for this assessment.

For the impact assessments, the methodology outlined by Energinet.dk and NIRAS was used. The methodology is based on a ranking of severity of impacts as negligible, minor, moderate or major depending on assessments of the *degree of disturbance, importance*, *likelihood* and the *duration* of effects.

7 Existing conditions

7.1 The use of Kriegers Flak area by non-breeding waterbirds

Neither the wind farm site nor the area covered by the cable trace to Rødvig house any local breeding waterbirds. Accordingly, the baseline description is focused on the occurrence of non-breeding waterbirds which stage and feed locally.

A recent review of wintering waterbird populations in the Baltic Sea based on co-ordinated censuses between 2007 and 2009 included the planned wind farm site on Kriegers Flak (Skov et al. 2011). In the Kriegers Flak area, including the wind farm site, Long-tailed Duck *Clangula hyemalis* is the only common species. The area shallower than 20 m generally holds the highest densities of waterbirds. Danish waterbird monitoring data from 2004 and 2008 (Petersen et al. 2006a, 2010) corroborate the findings for Long-tailed Duck. Gulls are common in the Kriegers Flak area, and most are associated with fishing activities. Less common species of waterbirds include Red-throated/Black-throated Diver *Gavia stellate/arctica* and Black Guillemots *Cepphus grylle*.

The review of waterbirds in the German EEZ by Garthe (2003, Table 6) shows the following patterns of seasonality on Kriegers Flak: Red-throated/Black-throated Divers (winter, spring), Common Eider (spring), Long-tailed Duck (winter, spring), Common Gull (winter, spring), Herring Gull (winter, spring, autumn), Great Black-backed

Gull (winter, spring, autumn), Lesser Black-backed Gull (spring, autumn), Common Guillemot (winter, spring), Razorbill (winter, spring) and Black Guillemot (winter, spring).

Table 6. Reported densities and abundance of staging/feeding waterbirds at Kriegers Flak.

Species	**Skov et al. 2011** **Durinck et al. 1994**	**IfAÖ 2003** **Kube et al. 2004a**
Red-throated/ Black-throated Diver (*Gavia stellata/arctica*)	Winter < 0.1 birds/km^2	0.1 - 0.37 birds/km^2
Common Eider (*Somateria mollissima*)	None in winter	Irregular, up to 1,000 birds during spring, late summer
Long-tailed Duck (*Clangula hyemalis*)	Winter 3 - 10 birds/km^2	Up to 10,000 birds during winter, spring
Common Scoter (*Melanitta nigra*)	None in winter	Irregular – peak density spring 0.45 birds/km^2
Velvet Scoter (*Melanitta fusca*)	None in winter	Uncommon
Little Gull (*Larus minutus*)	Winter < 0.01 birds/km^2	Up to 80 birds spring, autumn
Black-headed Gull (*Larus ridibundus*)	None in winter	Up to 50 birds spring, autumn
Common Gull (*Larus canus*)	Winter < 0.1 birds/km^2	Up to 500 birds winter, spring
Herring Gull (*Larus argentatus*)	Winter 1 – 4.99 birds/km2	Up to 3,000 birds winter, spring
Great Black-backed Gull (*Larus marinus*)	Winter < 0.1 birds/km^2	Up to 800 birds winter, spring, autumn
Razorbill (*Alca torda*)	Winter < 0.1 birds/km^2	Up to 500 birds winter, spring
Common Guillemot (*Uria aalge*)	Winter 0.1 – 0.99 birds/km^2	Up to 100 birds winter, spring
Black Guillemot (*Cepphus grylle*)	Winter 0.01 – 0.49 birds/km^2	Up to 130 birds winter

7.1.1 Long-tailed Duck

The observed densities in the survey data used as response variables in the models are displayed below (Figure 15). Patterns were similar in the different surveys, although the survey effort and extent differed markedly. Decreasing water depth, increasing distance to land and moderate sloping bottoms increased the probability of Long-tailed Duck presence in both binomial models (mid 1990es and late 2000es, Table 7). Distance to hard bottom was also influential in both models, while the filter feeder index was only influential in period 2 and distance to mud only important in period 1. In both positive (gamma) models water depth and distance to land had similar shapes (Figure 16 and Figure 17). AIS (decreasing shipping) and all substrate layers were included in the positive model for period 1. The substrate layers indicated that moderate distances to sandy and hard bottom and increasing distance to muddy bottoms increases the probability of higher densities of long-tailed ducks. In the model for period 2 the probability for higher densities increased with decreasing distance to hard bottoms and moderate slope.

The interaction between X and Y coordinates was also included as it significantly improved the models. We found strong spatial autocorrelation in the binomial model for period 1 and we therefore extended the GAM to a GAMM including a corAR1 correlation structure. The GAMM model was capable of accounting for most of the spatial autocorrelation. In the other model residuals the Moran's I values (Spatial autocorrelation) were very low indicating that the GAMs were not violating the assumption of independent residuals (spatial autocorrelograms and model diagnostics are shown in Appendix A).

As deviance explained cannot be readily calculated for a GAMM the adjusted R^2 value was used as a measure of variance explained, while for the GAM models deviance explained was used. The variance explained was somewhat higher in the models for Period 1. However, the periods should not be directly compared as the sample size and resolution (of the original survey data) differed greatly. The evaluation statistic also indicated a reasonable predictive ability for all models, with a clear agreement between predicted and observed values in the evaluation data set.

The highest densities were predicted in southern parts of the study area in the Pomeranian Bay and west of Rügen, other areas also used by the long tailed ducks were coastal areas and offshore banks like Kriegers Flak (Figure 18). According to the models the extent of important areas was wider during period 1 in comparison to period 2. However, the differences might be due to the differences in survey effort and extent. Densities were much higher during period 1, - approximately a factor 10 compared to Period 2. This was also evident on Kriegers Flak where maximum densities of 100 birds/km^2 were predicted in Period 1 compared to densities of 10 birds/km^2 in Period 2. The area covered by the cable trace to Rødvig was characterised by low densities during both periods.

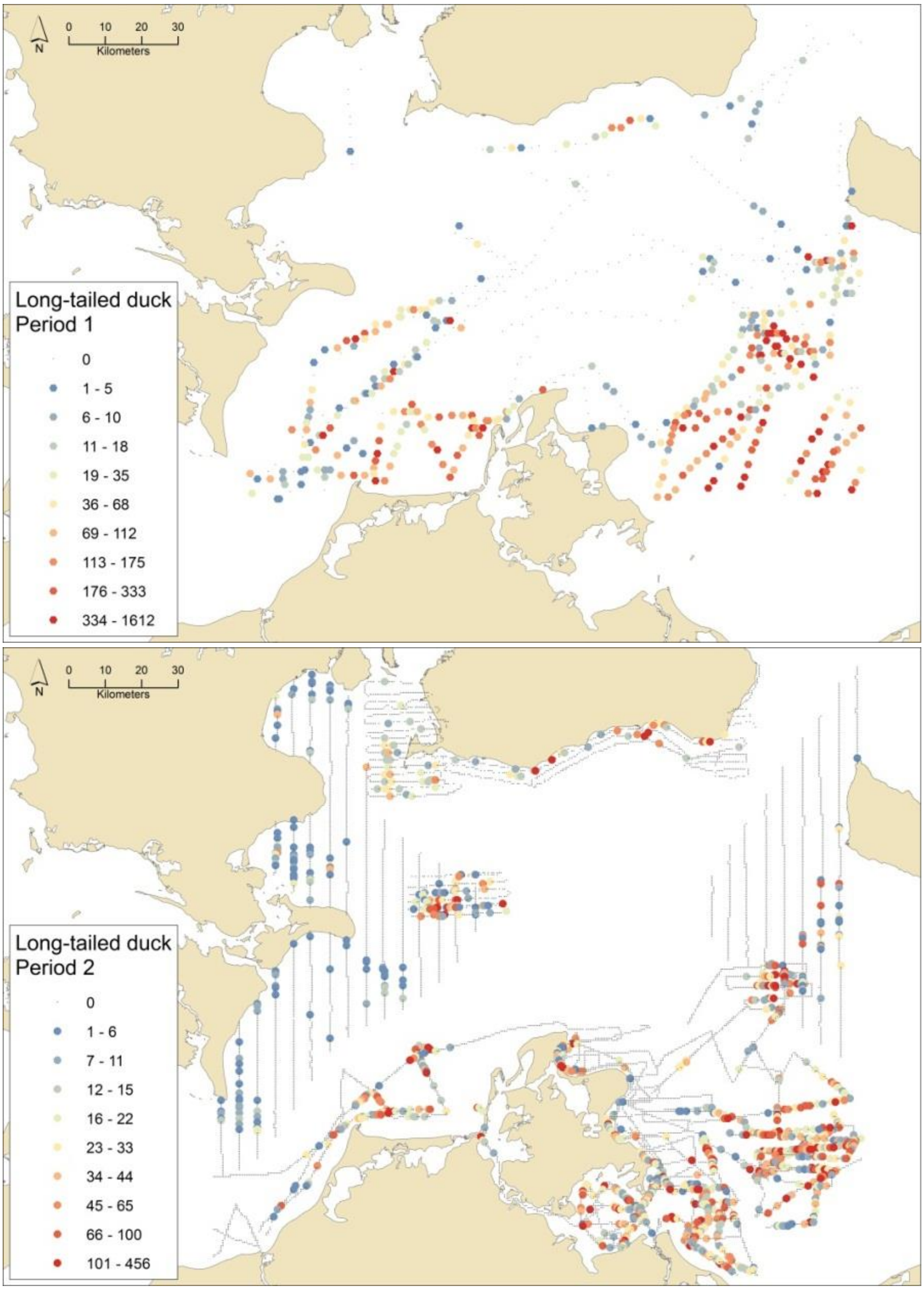


Figure 15. Survey coverage and observed Long-tailed Duck densities (average number per km^2 in 500x500 m grid cells) during the two periods (period 1 1987-1993, period 2 2004-2009).

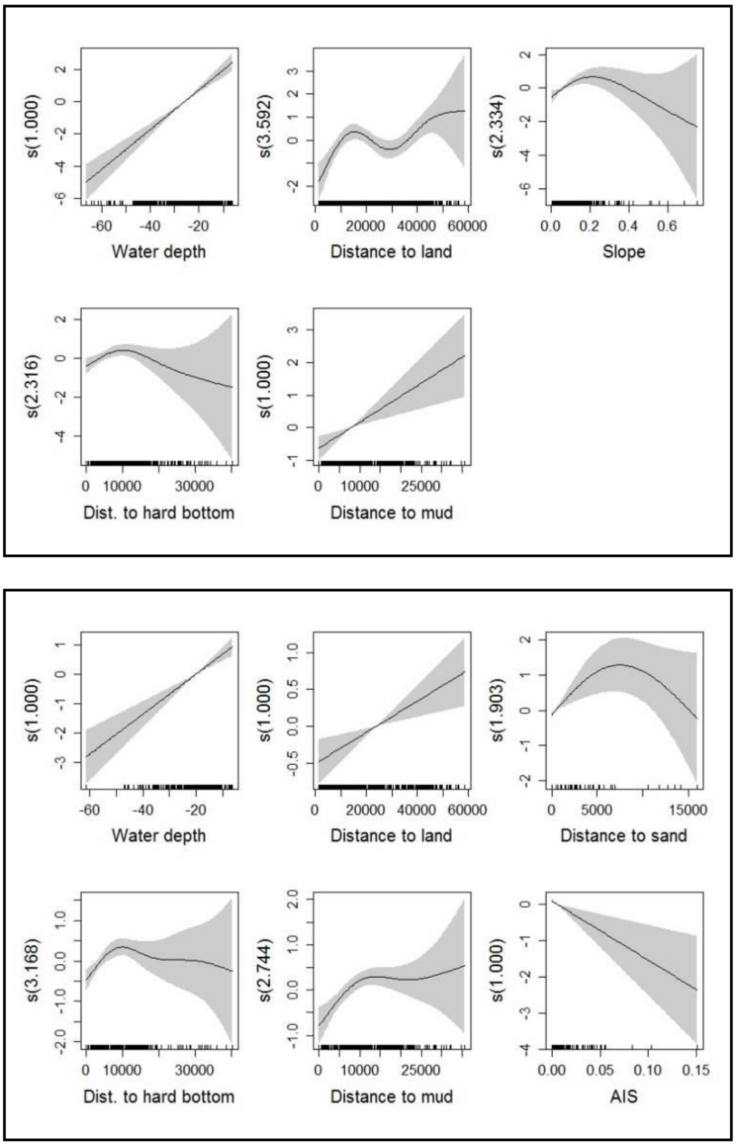
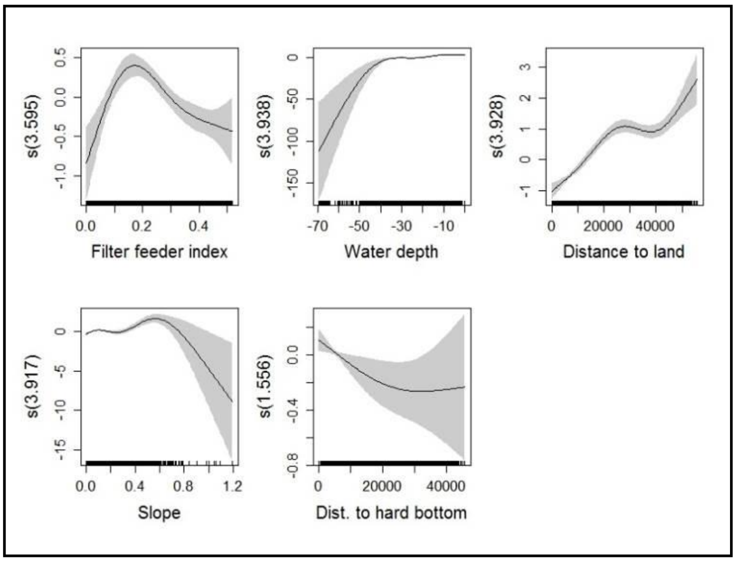


Figure 16. Response curves of the binomial GAMM (upper) and gamma GAM (lower) for the long-tailed duck during period 1. The values of the environmental predictor are shown on the X-axis and the probability on the Y-axis on the scale of the linear predictor. The degree of smoothing is indicated in the title of the Y-axis. The shaded areas and the dotted lines show the 95% Bayesian confidence intervals.



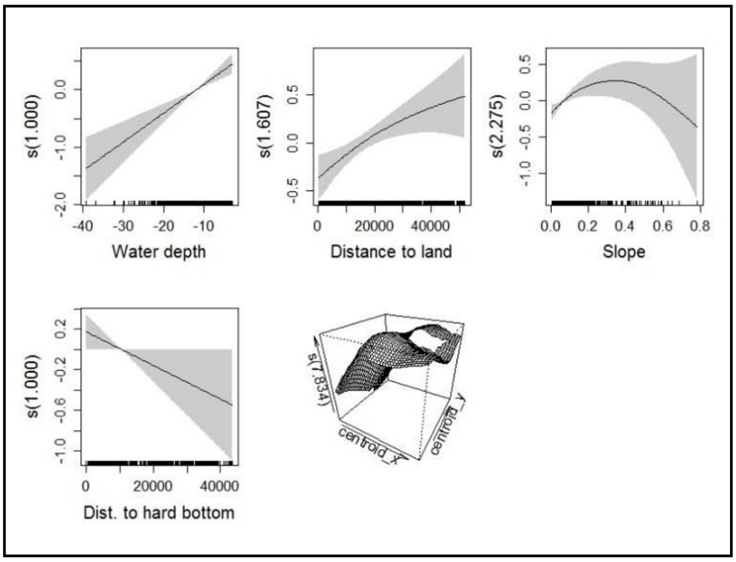


Figure 17. Response curves of the binomial (upper) and gamma (lower) GAMs for the long-tailed duck during period 2. The values of the environmental predictor are shown on the X-axis and the probability on the Y-axis on the scale of the linear predictor. The degree of smoothing is indicated in the title of the Y-axis. The shaded areas and the dotted lines show the 95% Bayesian confidence intervals.

Table 7. Approximate significance (Chi square and F-values) for the smooth terms included in the two part GAMs for both periods for the Long-tailed Duck. Non-important variables which were not included in the models are indicated by a dash. Adjusted R-square values or deviance explained are given as an indication of variance explained by the models. Evaluation statistics AUC (for the binomial models) and Spearman's correlation coefficient for the combined predictions are given.

Long-tailed duck Period 1	**Binomial**		**Gamma**	
	F	p-value	F	p-value
Depth	79.51	<0.01	37.21	<0.01
Distance to land	3.91	<0.01	10.07	<0.01
Slope	5.35	<0.01	-	-
Distance to sand	-	-	6.47	<0.01
Dist. to hard bottom	3.40	0.03	3.37	0.01
Distance to mud	12.09	<0.01	5.03	<0.01
AIS	-	-	10.03	<0.01
R-sq.(adj)	0.47			
Dev.exp.			26.50%	
N	601		367	
AUC	0.88			
Spearman's corr.	0.64			
Long-tailed duck Period 2	**Binomial**		**Gamma**	

	Chi.sq	p-value	F	p-value
Filter feeder index	42.396	<0.01	-	-
Depth	449.996	<0.01	25.402	<0.01
Distance to land	202.68	<0.01	5.103	<0.01
Slope	42.288	<0.01	3.64	0.02
Dist. to hard bottom	7.857	0.02	4.014	0.05
X,Y	-	-	30.279	<0.01
Dev. exp.	17.30%		19.30%	
N	8241		1041	
AUC	0.79			
Spearman's corr.	0.33			

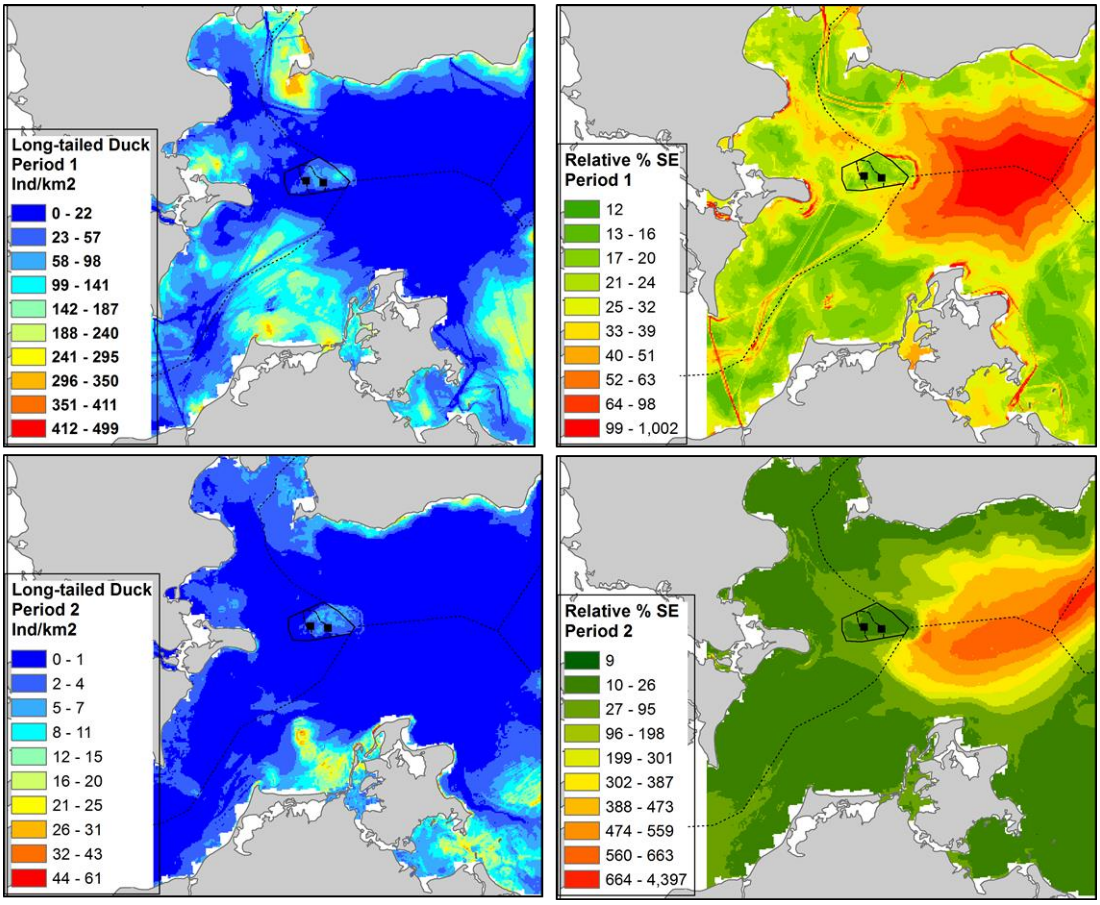
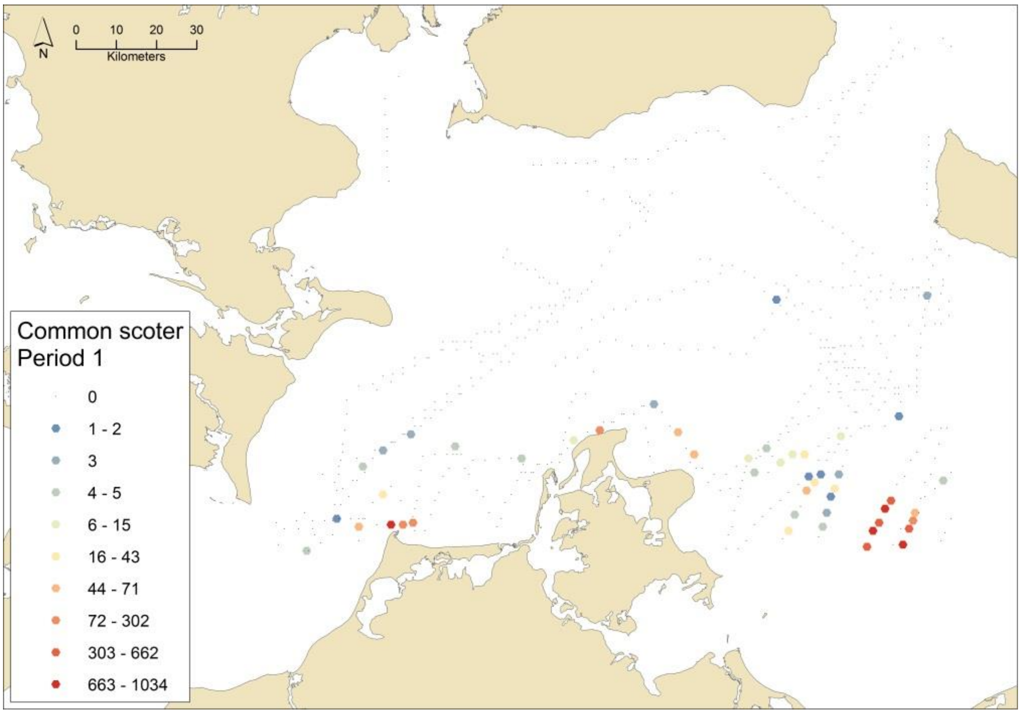


Figure 18. Predicted densities of wintering Long-tailed Duck densities for the two different periods to the left and the respective associated model standard errors as percentage to the right.

7.1.2 Common Scoter

The observed densities in the survey data used as response variables in the models are displayed below (Figure 19). Patterns were similar between survey periods although the survey effort and extent differed markedly, the areas with presences around Falsterbo and North of Møn in the second period was for example not surveyed in the first period. Water depth (decreasing) was included in both binomial models (in both period 1 and 2, Figure 20, Figure 21Table 8). Distance to hard bottom and mud was also influential in period 1, while the filter feeder index, distance to land and X, Y coordinates were influential in the binomial model for period 2. In the positive model for period 1 water depth, distance to land and X, Y coordinates were included. In the positive model for period 2 filter feeder index distance to mud and X,Y coordinates were included. No strong spatial autocorrelation in the model residuals was found, indicating that the GAMs were not violating the assumption of independent residuals (spatial autocorrelograms and model diagnostics are shown in Appendix A).

The variance explained (deviance explained) was more or less the same for both binomial parts. The positive part for period 1 was only based on 47 samples so it should not be compared to the positive model for period 2. The evaluation statistics were acceptable for both periods. The highest densities were predicted in southern parts of the study area in the Pomeranian Bay, west of Rügen, around Falsterbo and in the Danish Bays, while no birds or very low densities were predicted for Kriegers Flak (Figure 22). The area covered by the cable trace to Rødvig was characterised by low densities during both periods. The densities during period 1 are over predicted and are also based on a small sample size. The predictions for period 2 are more reliable and interpretable.



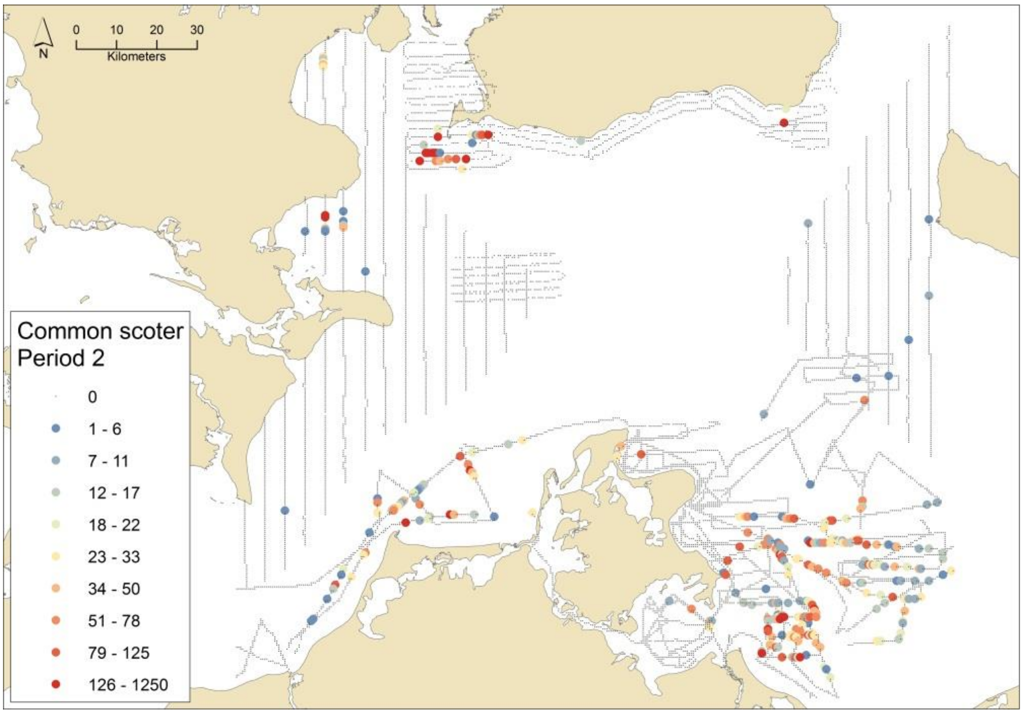


Figure 19. Survey coverage and observed Common Scoter densities (average number per km^2 in 500x500 m grid cells) during the two periods (period 1 1987-1993, period 2 2004-2009.

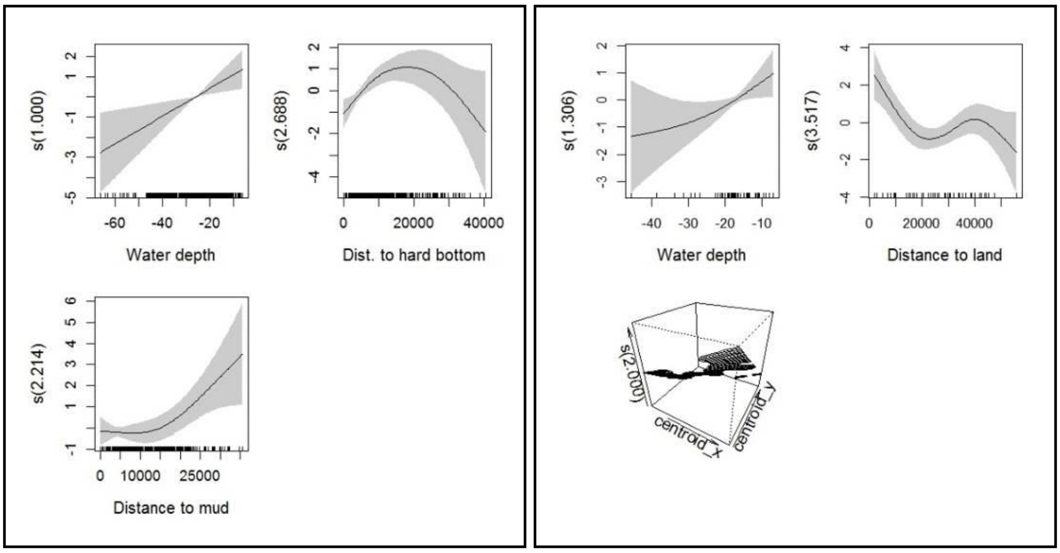


Figure 20. Response curves of the binomial (left) and gamma (right) GAMs for the Common Scoter during period 1. The values of the environmental predictor are shown on the X-axis and the probability on the Y-axis on the scale of the linear predictor. The degree of smoothing is indicated in the title of the Y-axis. The shaded areas and the dotted lines show the 95% Bayesian confidence intervals.

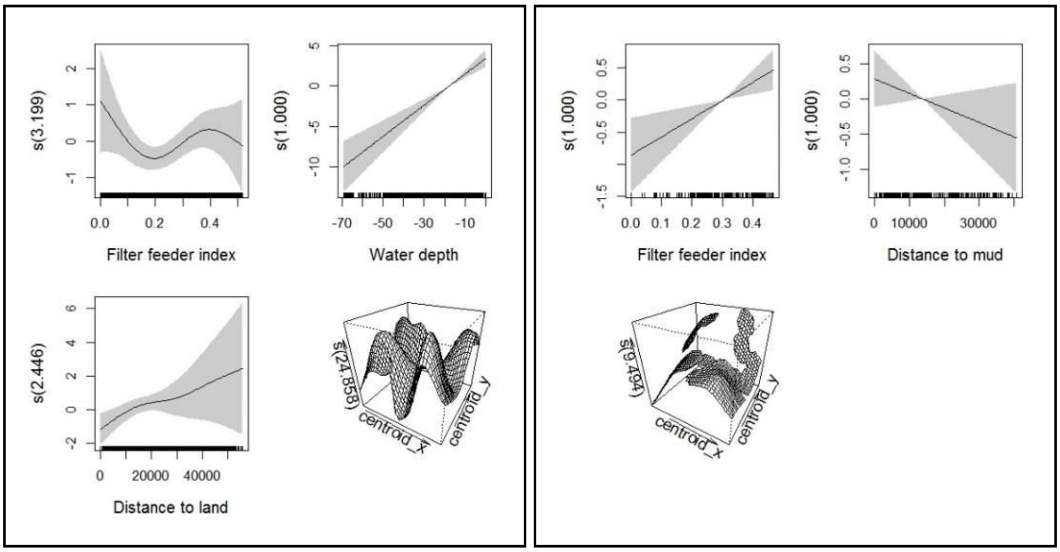


Figure 21. Response curves of the binomial (left) and gamma (right) GAMs for the Common Scoter during period 2. The values of the environmental predictor are shown on the X-axis and the probability on the Y-axis on the scale of the linear predictor. The degree of smoothing is indicated in the title of the Y-axis. The shaded areas and the dotted lines show the 95% Bayesian confidence intervals.

Table 8. Approximate significance (Chi square and F-values) for the smooth terms included in the two part GAMs for both periods for the Common Scoter. Deviance explained are given as an indication of variance explained by the models. Evaluation statistics AUC (for the binomial models) and Spearman's correlation coefficient for the combined predictions are given.

Common scoter Period 1	Binomial		Gamma	
	Chi.sq	p-value	F	p-value
Depth	7.88	<0.01	2.04	0.15
Distance to land	-	-	5.50	<0.01
Dist. to hard bottom	15.76	<0.01	-	-
Distance to mud	10.53	0.01	-	-
X, Y	-	-	8.77	<0.01
Dev. exp.	24.20%		67.30%	
n	601		47	
AUC	0.76			
Spearman's corr.	0.25			
Common scoter Period 2	**Binomial**		**Gamma**	
	Chi.sq	p-value	F	p-value
Filter feeder index	9.25	0.04	8.75	<0.01
Depth	39.72	<0.01	-	-
Distance to land	9.06	0.03	-	-
Distance to mud	-	-	2.01	0.16
X, Y	161.12	<0.01	4.07	<0.01
Dev. exp.	24.60%		29.40%	
n	8241		292	
AUC	0.87			
Spearman's corr.	0.21			

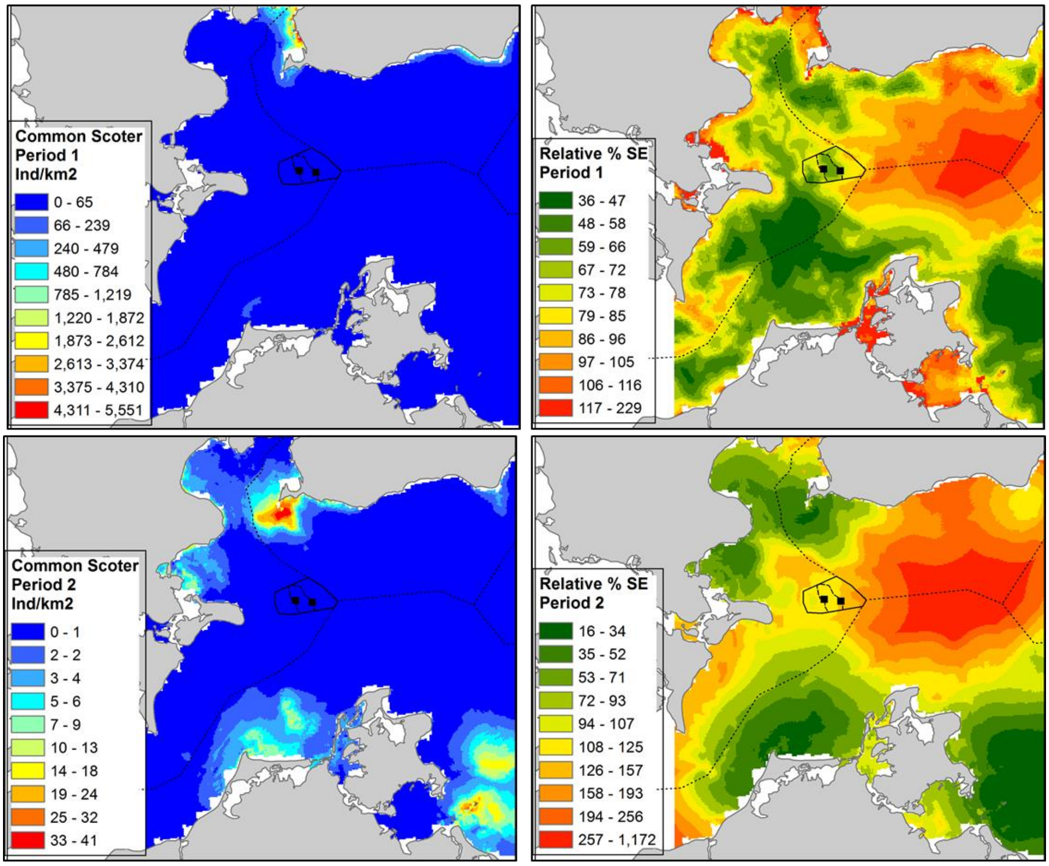


Figure 22. Predicted densities of wintering Common Scoter densities for the two different periods to the left and the respective associated model standard errors as percentage to the right.

7.1.3 Velvet Scoter

The observed densities in the survey data used as response variables in the models are displayed below (Figure 23). Patterns were similar during both survey periods with highest densities observed on Oderbank. According to the binomial model for period 1 the probability of presence of velvet scoters increased with moderate values of the filter feeder index, decreasing water depth increasing distance to land, decreasing number of ships, increasing distance to hard bottoms and increasing distance to mud (Table 9). In the positive model for period 1 only the interaction between X, Y coordinates and distance to mud was selected. In the binomial model for period 2, filter feeder index (complex response) was included together with decreasing water depth, increasing distance to land and the X, Y coordinates. In the positive part the model indicates that the probability of higher densities of Velvet Scoter increased with higher values of the filter feeder index and decreasing distance to mud (Figure 24, Figure 25). The X, Y interaction term was also included. No strong spatial autocorrelation in the model residuals was found, indicating that the GAMs were not violating the assumption of independent residuals (spatial autocorrelograms and model diagnostics are shown in Appendix A).

The variance explained (deviance explained) was similar for both binomial parts. As the sample size was much smaller in the data from period 1 the variance explained in the positive part should not be directly compared to that of period 2. However, both models had a reasonable explanation degree. The evaluation statistics were good for both periods particularly the AUC value. The highest densities were predicted on Oderbank in agreement with the observe densities, and no birds were predicted for Kriegers Flak (Figure 26). The area covered by the cable trace to Rødvig was characterised by low densities during both periods.

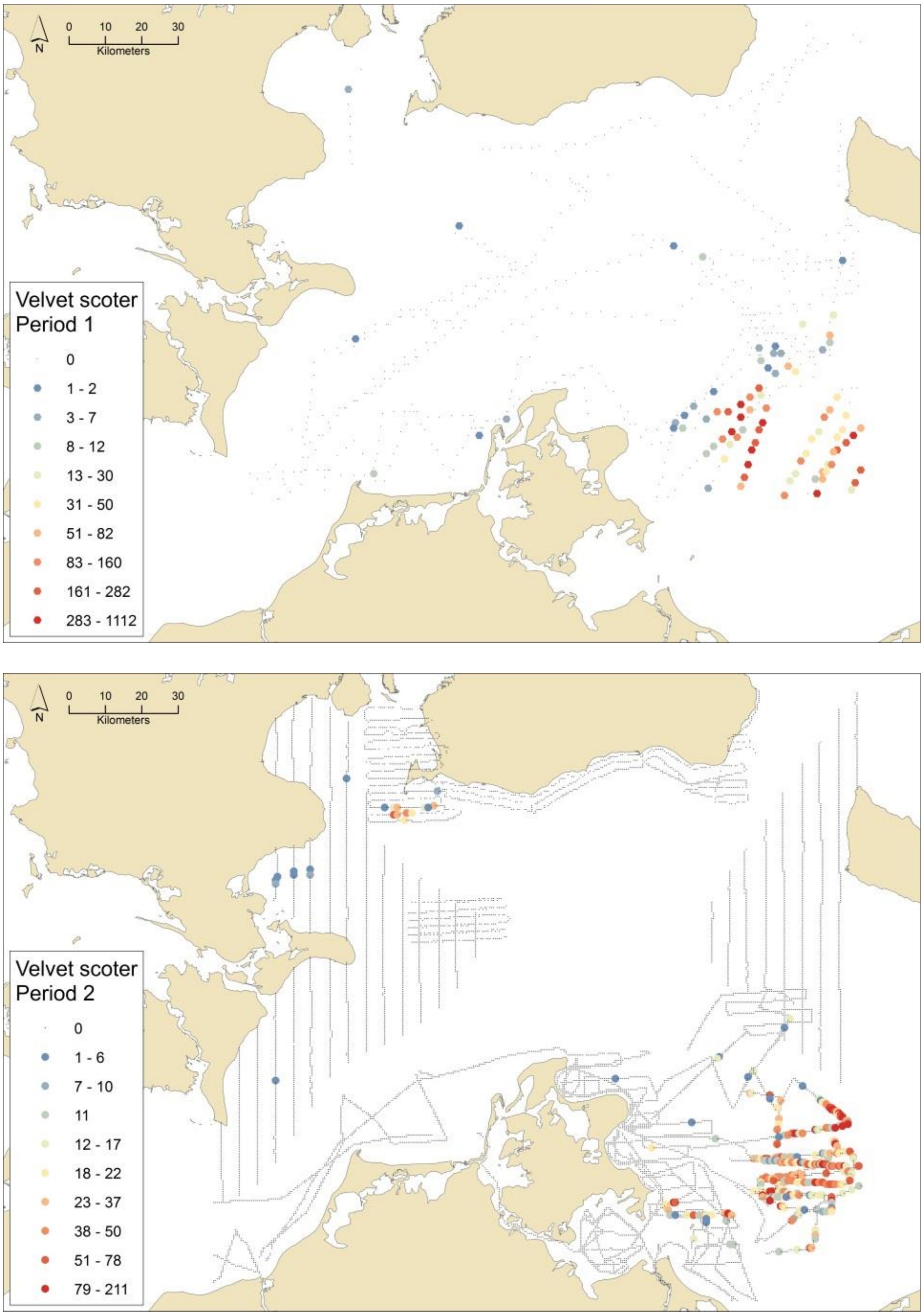


Figure 23. Observed Velvet Scoter densities (average number per km² in 500x500 m grid cells) during the two periods (period 1 1987-1993, period 2 2004-2009.

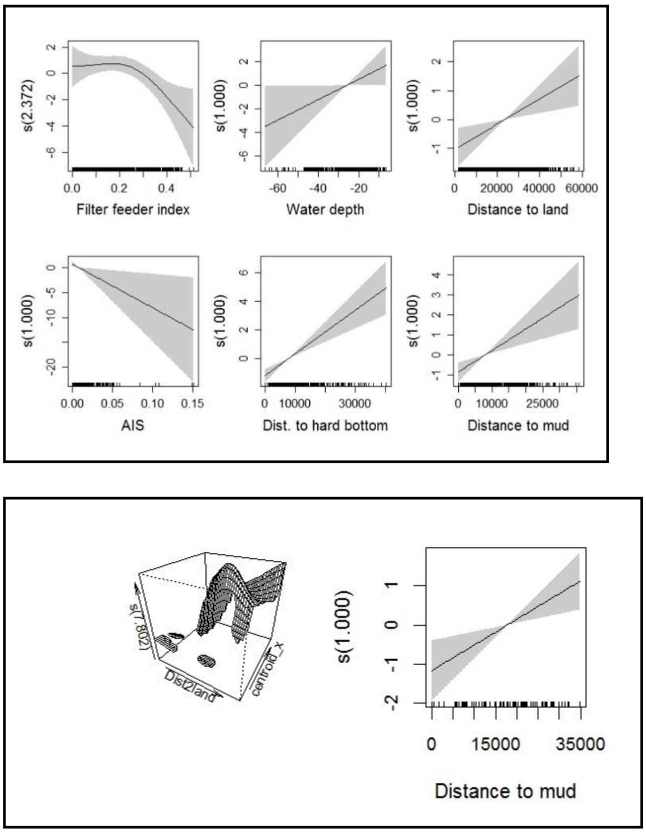


Figure 24. Response curves of the binomial (upper) and gamma (lower) GAMs for the Velvet Scoter during period 1. The values of the environmental predictor are shown on the X-axis and the probability on the Y-axis on the scale of the linear predictor. The degree of smoothing is indicated in the title of the Y-axis. The shaded areas and the dotted lines show the 95% Bayesian confidence intervals.

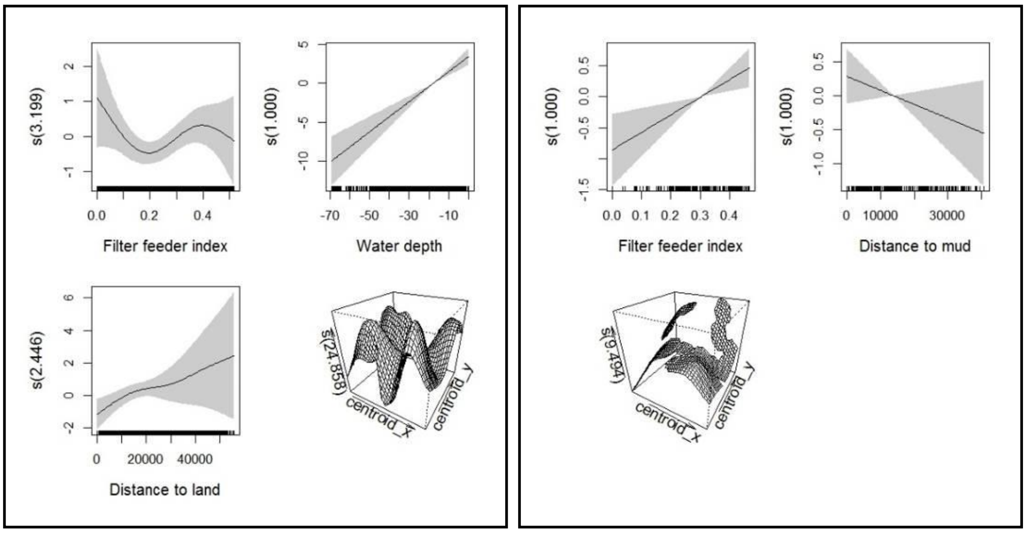


Figure 25. Response curves of the binomial (left) and gamma (right) GAMs for the velvet scoter during period 2. The values of the environmental predictor are shown on the X-axis and the probability on the Y-axis on the scale of the linear predictor. The degree of smoothing is indicated in the title of the Y-axis. The shaded areas and the dotted lines show the 95% Bayesian confidence intervals.

Table 9. Approximate significance (Chi square and F-values) for the smooth terms included in the two part GAMs for both periods for the Velvet Scoter. Deviance explained are given as an indication of variance explained by the models. Evaluation statistics AUC (for the binomial models) and Spearman's correlation coefficient for the combined predictions are given.

Velvet scoter Period 1	Binomial		Gamma	
	Chi.sq	p-value	F	p-value
Filter feeder index	12.04	0.01	-	-
Depth	4.17	0.04	-	-
Distance to land	8.41	<0.01	-	-
AIS	5.70	0.02	-	-
Dist. to hard bottom	27.89	<0.01	-	-
Distance to mud	12.48	<0.01	9.34	<0.01
Distance to land, X	-	-	5.35	<0.01
Deviance explained	46.60%		54.50%	
N	601		83	
AUC	0.93			
Spearman's corr.	0.54			
Velvet scoter Period 2	Binomial		Gamma	
	Chi.sq	p-value	F	p-value
Filter feeder index	9.25	0.04	-	-
Depth	39.72	<0.01	0.52	0.55
Distance to land	9.06	0.03	-	-
Dist. To hard bottom	161.12	<0.01	2.48	0.07
X, Y	-	-	2.26	<0.01
Deviance explained	42%		22.70%	
n	8241		294	
AUC	0.93			
Speramn's corr.	0.27			

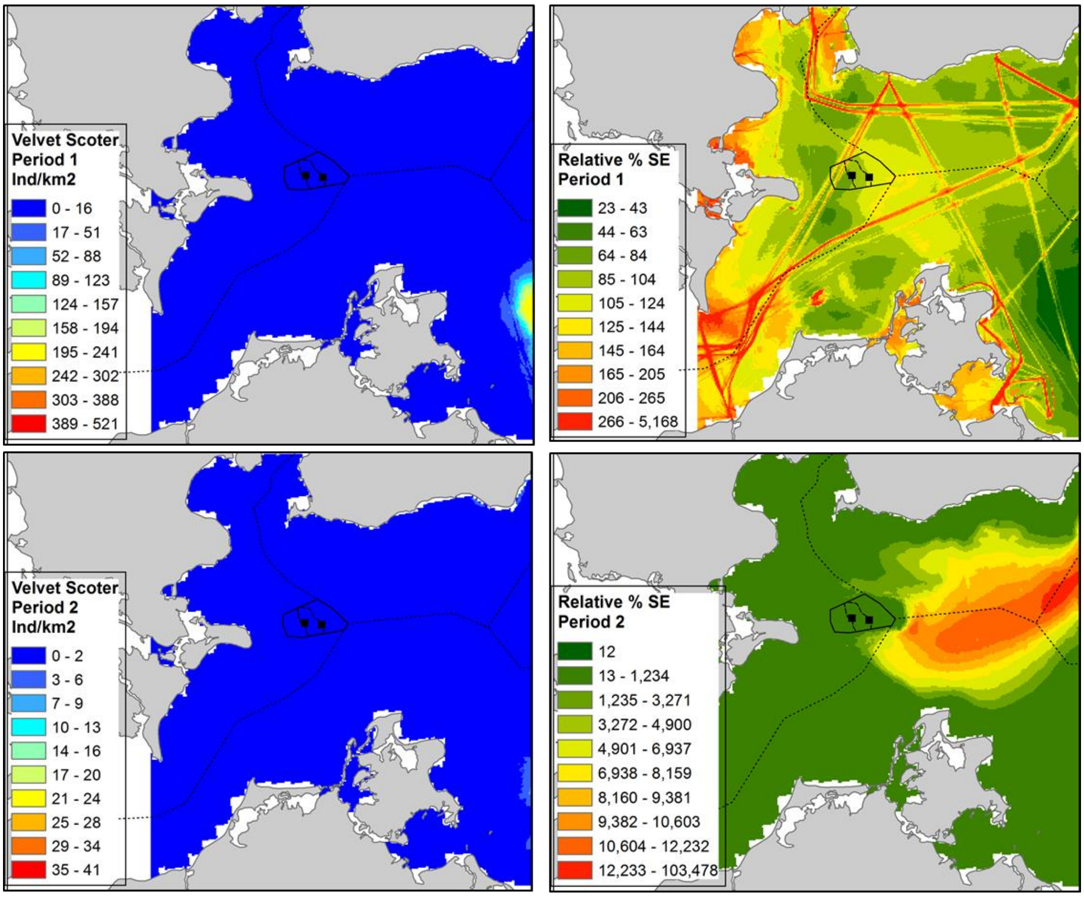


Figure 26. Predicted densities of wintering Velvet Scoter densities for the two different periods to the left and the respective associated model standard errors as percentage to the right.

7.2 Bird migration across the Arkona Basin

Baseline investigations undertaken in relation to the planned wind farms on the Swedish and German parts of Kriegers Flak and Adler Ground (Arkona Becken Südost, Ventotec Ost 2) have shown that the migration of waterbirds trough the Arkona Basin seems mainly to take place over a relatively broad front, and is dominated by Common Eider, Barnacle Goose *Branta leucopsis* and Common Scoter. The radar study by Petterson (2003) from the Swedish south coast indicated that 30% of the waterbirds were moving parallel to the coast within a distance of 10 km from the coast, while the remaining 70% were dispersed over a wide front without any obvious use of specific corridors.

The migration of landbirds through the region is markedly different during day and night both with respect to dominating species and migration altitude. Recorded flight intensities during night indicate that the flux of birds peaks on very few nights (Kube et al. 2004b). During spring, nocturnal migration was most intense 5-6 hours after sunset, and during autumn 3-4 hours after sunset, indicating recruitment areas in Mecklenburg and southern Sweden, respectively (Kube et al. 2004b). Diurnal migration was less intense, and showed no obvious peaks.

The diversity of bird migration can be quite high, as shown by counts of visual migration at Kriegers Flak (65 days German part) in which 116 species were observed (see example on Figure 27). The vertical distribution of migrating birds showed the same general trends documented by other studies that birds tend to fly at lower altitudes during head winds, and at lower altitudes during the day as compared to during the night. Overall most bird echoes during night were recorded in the lower 200 m (IfAÖE 2003).

Below is a detailed description of the migration of the different species raptors and Common Crane through the region. The descriptions are almost entirely based on the baseline investigations undertaken as part of this EIA, and cover assessment of the proportion of birds crossing open sea in the Arkona Basin and the variation in flight altitude as a function of distance to the coast and weather conditions.

Figure 27. Honey Buzzard.

7.2.1 Observation effort

Overviews of the observation effort during the baseline investigation of bird migration are given in Table 10 and Table 11. The effort was focused on tracking migrating raptors and Common Crane along the Danish and Swedish coasts of the Arkona Basin (see example on Figure 28), as well as from the FINO 2 offshore platform and the Falsterbo Lighthouse, both located offshore. A total of 21 days were covered during spring and 32 during autumn, which means that observations were made during approximately 30% of the daytime migration periods for Common Crane and raptors. As Common Crane constituted the primary target of the observations most of the effort was concentration on the main migration periods for Common Crane; mid March – mid April and late September – late October.

Figure 28. Observations being made at Stevns Klint.

Table 10. Overview of effort and methods during the baseline investigations spring 2013.

Date	Falsterborev Light house Rangefinder tracking	Danish coast Stevns/Møns Klint / Sydvestpynten Rangefinder tracking	Sweden S coast Rangefinder tracking
31-Mar			X
01-Apr		X	X
02-Apr		X	X
03-Apr		X	X
04-Apr	X	X	X
06-Apr		X	
07-Apr			X
08-Apr	X		X
15-Apr			X
16-Apr		X	
17-Apr			X
20-Apr	X		
21-Apr	X		X
12-May			X
3-May		X	
14-May		X	
15-May		X	
17-May		X	
20-May		X	
23-May		X	
24-May		X	

Table 11. Overview of effort and methods during the baseline investigations autumn 2013.

Date	FINO 2 Radar and rangefinder tracking	Danish coast Stevns/Møns Klint Rangefinder tracking	Sweden S coast Rangefinder tracking
21-aug		X	X
23-aug		X	X
24-aug		X	X
27-aug			X
28-aug	X		X
29-aug	X	X	X
30-aug	X		X
31-aug		X	X
3-sep	X	X	X
4-sep		X	X
5-sep		X	X
6-sep			X
14-sep			X
21-sep			X
24-sep		X	X
25-sep	X		
26-sep		X	X
27-sep		X	X
28-sep	X		X
29-sep		X	X
30-sep			X

Date	FINO 2 Radar and rangefinder tracking	Danish coast Stevns/Møns Klint Rangefinder tracking	Sweden S coast Rangefinder tracking
1-okt		X	X
2-okt		X	X
6-okt		X	X
10-okt	X		
11-okt		X	X
12-okt		X	X
16-okt	X		
18-okt		X	X
19-okt		X	X
25-okt	X		

During spring 2015, a dedicated behavioural study of the responses of Common Crane to an offshore wind farm was undertaken at the Baltic 2 offshore wind farm located in the German part of Kriegers Flak. Observations with radar and rangefinder were made by two observers from the FINO 2 platform as well as from a boat between 19 March to 20 April 2015. A total of 12 days were obtained from the FINO 2 platform and a total of 8 days from the boat.

7.2.2 Sparrowhawk

7.2.2.1 *Spatial distribution and migration direction*

According to Karlsson et al. (2004) 16,000 Sparrowhawks leave Falsterbo on an average autumn season. Based on the rangefinder data collected during the baseline at Falsterbo only 5% of the birds have directions indicating that they will cross the Arkona Basin, whereas the vast majority of directions are concentrated around SW in the direction of Stevns Klint in Denmark (Figure 29, Figure 30). Although some birds may leave Sweden before they reach Falsterbo the above proportion is most likely a reasonable approximation of the number of Sparrowhawks crossing, which using the mean figure from Falsterbo equals 800 birds. No figures on spring migration of raptors through the region are available.

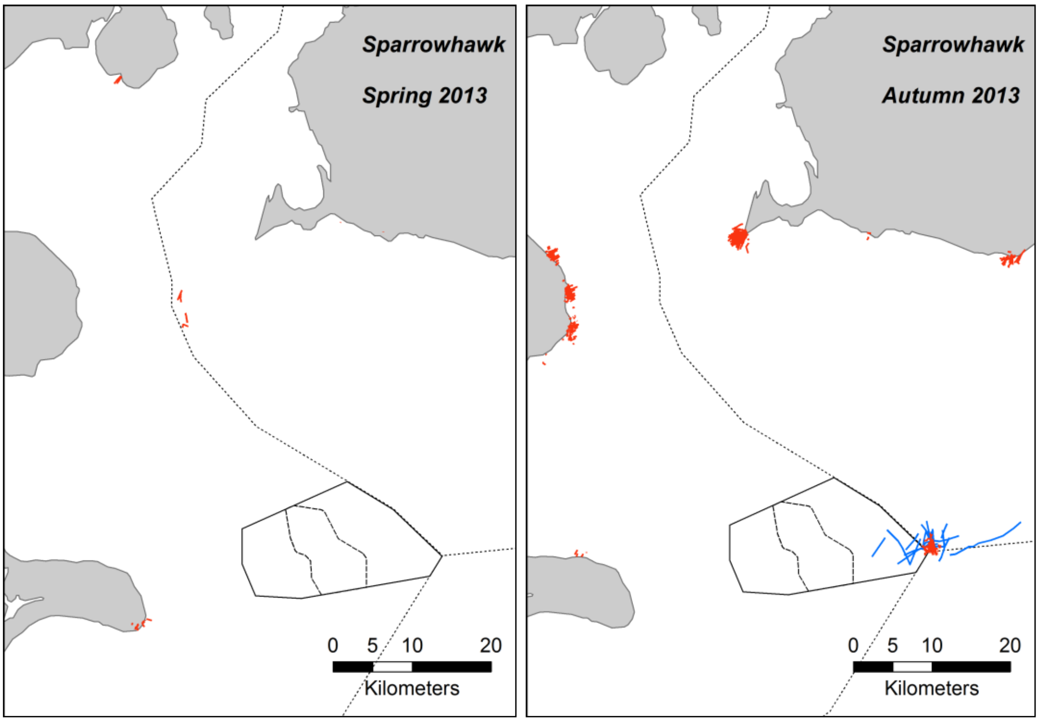


Figure 29. Migration tracks of Sparrowhawk collected in the study area, spring and autumn 2013. Radar-based tracks are marked by blue lines, and rangefinder-based tracks by red lines.

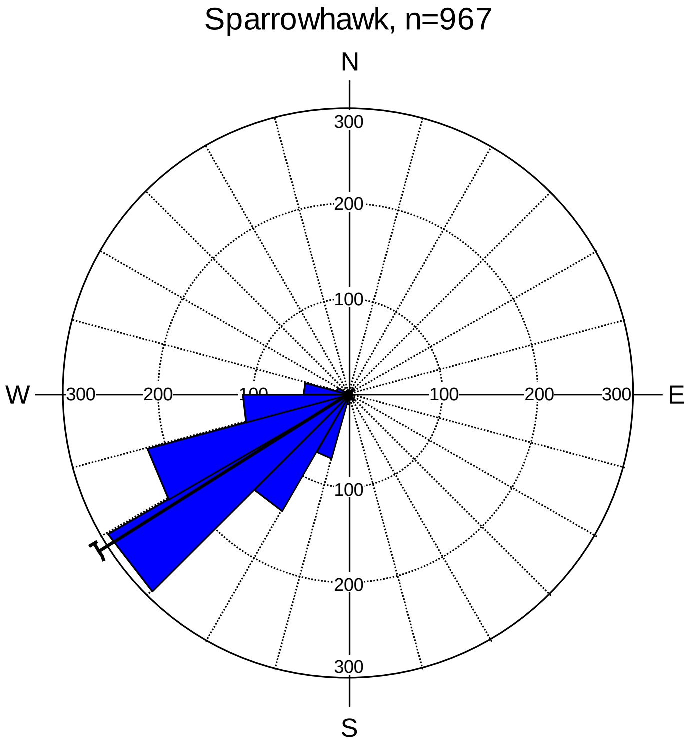


Figure 30. Sampled migration directions of Sparrowhawk at Falsterbo, autumn 2013. Numbers on the Y-axes refer to sample size (number of recordings by laser rangefinder). Each wedge represents a sector of 15°. The mean direction is indicated by the black line running from the center of the graph to the outer edge. The arcs extending to either side represent the 95% confidence limits of the mean directions.

7.2.2.2 ***Migration altitude***

The patterns of flight altitude displayed by migrating Sparrowhawks (Figure 31) are typical for soaring migrants with a wide range of altitudes as the birds leave land, followed by descending altitudes as the birds cross the Baltic Sea. The angle of descend is significantly different between species (Table 12), and for Sparrowhawk it also differs significantly during different wind directions with the steepest angle in tail winds when birds often initiate migration at higher altitudes (Table 13, Figure 32). The resulting frequency distributions of flight altitudes at the departure points on the Swedish coast, at the arrival points on the Danish east coast and at FINO 2 on Kriegers Flak clearly document that almost all Sparrowhawks cross the Baltic at altitudes below 200 m, and most at altitudes below 100 m (Figure 33).

Figure 31. Sparrowhawk.

Table 12. Results of homogeneity of slope test testing whether different species have different responses of altitude to distance to land. Only the results for the interaction between species and distance to land are shown for the DHI rangefinder data collected from the Swedish coast autumn 2013. The test is highly significant, i.e. there is a significant difference in the descending angle from departing coast between the different species.

Value	F	Df	p
4857487	11.38	16	< 0.00001

Table 13. Results of homogeneity of slope test testing whether tracks of Sparrowhawk during different wind directions have different responses of altitude to distance to land. Only the results for the interaction between wind direction and distance to land are shown for the DHI rangefinder data collected from the Swedish coast autumn 2013.

Value	F	Df	p
705447	22.60	3	< 0.00001

The GAMM flight model for the Sparrowhawk indicates that the birds fly higher in tail winds (northerly winds) and descend in altitude after leaving the coast (Figure 34). They also fly higher in lower wind speeds and increasing clearness and air pressure (Figure 34). The predictive accuracy of the GAMM was high, with a good agreement between observed and predicted altitudes, a Spearman's rank correlation of 0.59, when the model was evaluated on semi-independent data (Table 14, Figure 35). The adjusted R^2 indicated a reasonable good fit (Table 14). The model successfully accounted for the strong temporal and spatial autocorrelation in the track data by using the correlation structure and random term (serial and spatial autocorrelograms and model diagnostics are shown in Appendix A).

According to the model predictions the birds fly on average within rotor height of the 10 MW turbines at Kriegers Flak during all wind conditions (Figure 36). In average the Sparrowhawks flew higher in tailwinds in comparison to headwinds according to the model, which is in agreement with the observations. Graphs of the predictions including model standard errors are shown in the Appendix A.

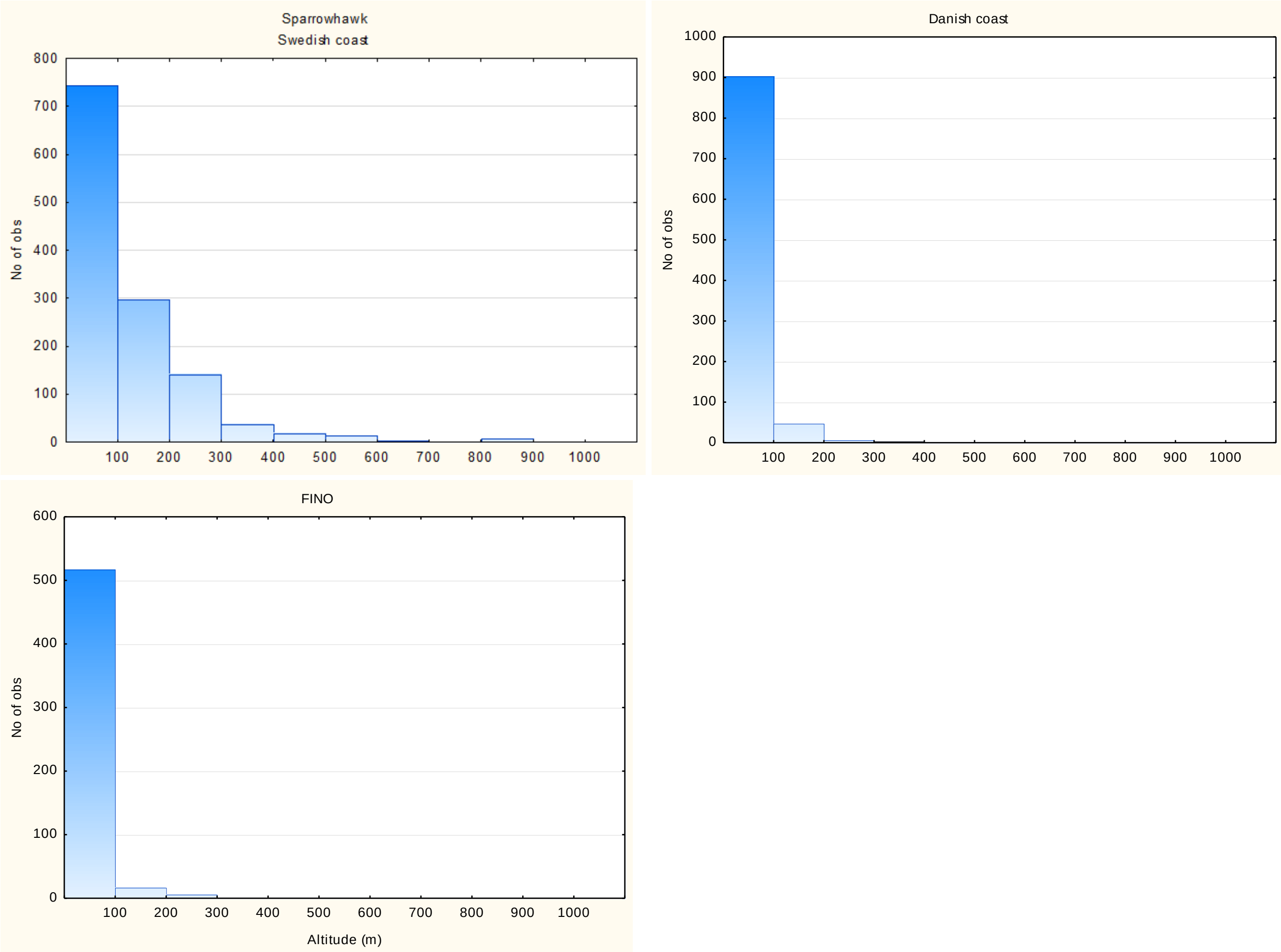


Figure 32. Frequency distribution of altitude measurements of Sparrowhawk by laser rangefinder at the Swedish south coast, at the Danish coast and at FINO 2 during autumn 2013.

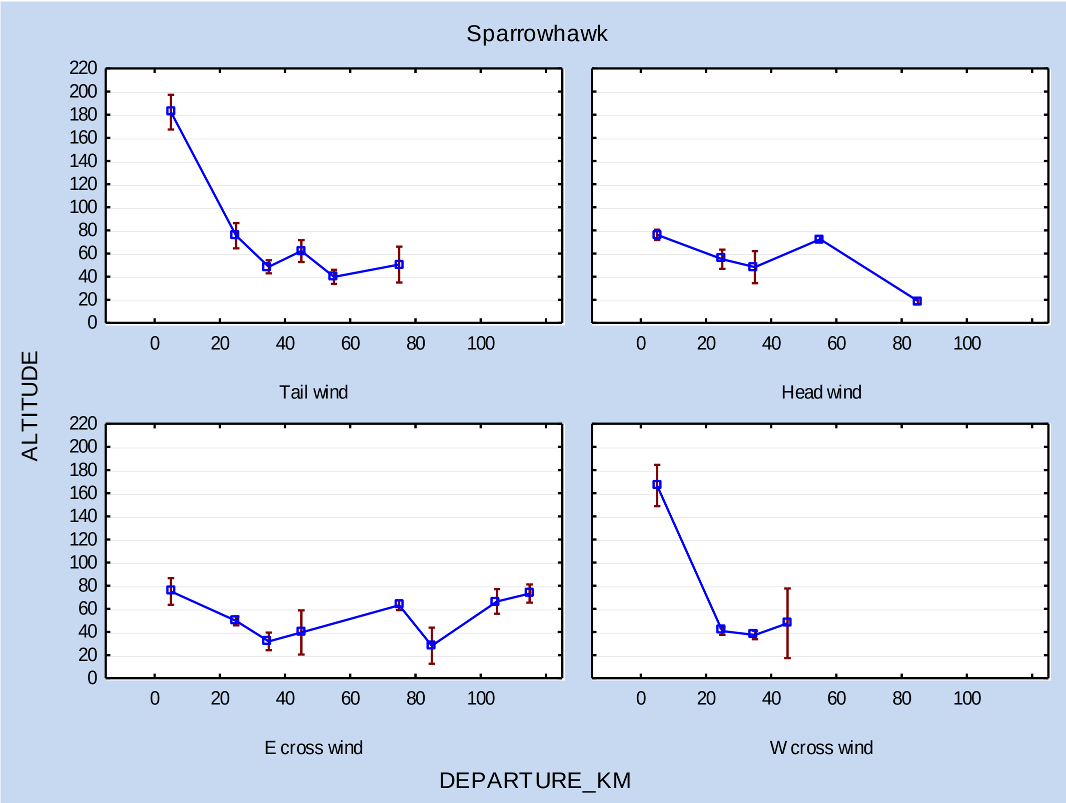


Figure 33. Changes in sampled altitude of Sparrowhawk by laser rangefinder during 2013 in relation to distance from the departure coast (north Germany in spring and south Sweden in autumn). Mean and confidence interval are given for different distances from departing coast and wind direction.

Table 14. Significance and t- and F-values for the fixed parametric (wind directions) and smooth terms included in the GAMMs for the Sparrowhawk. Adjusted R^2 indicates the variance explained by the model and the Spearman's correlation coefficient the agreement between predicted and evaluated altitudes (by a split sample evaluation approach). Number of samples used in the analysis is shown on the bottom row.

		F-value	p-value
Smooth	Distance to coast: Wind direction	10.950	<0.01
	Wind speed 200 m	1.441	0.23
	Clearness	9.027	<0.01
	Air pressure	2.452	0.12
R-sq. (adj)		0.31	
Spearman's corr.		0.59	
N of tracks (samples)		410 (2529)	

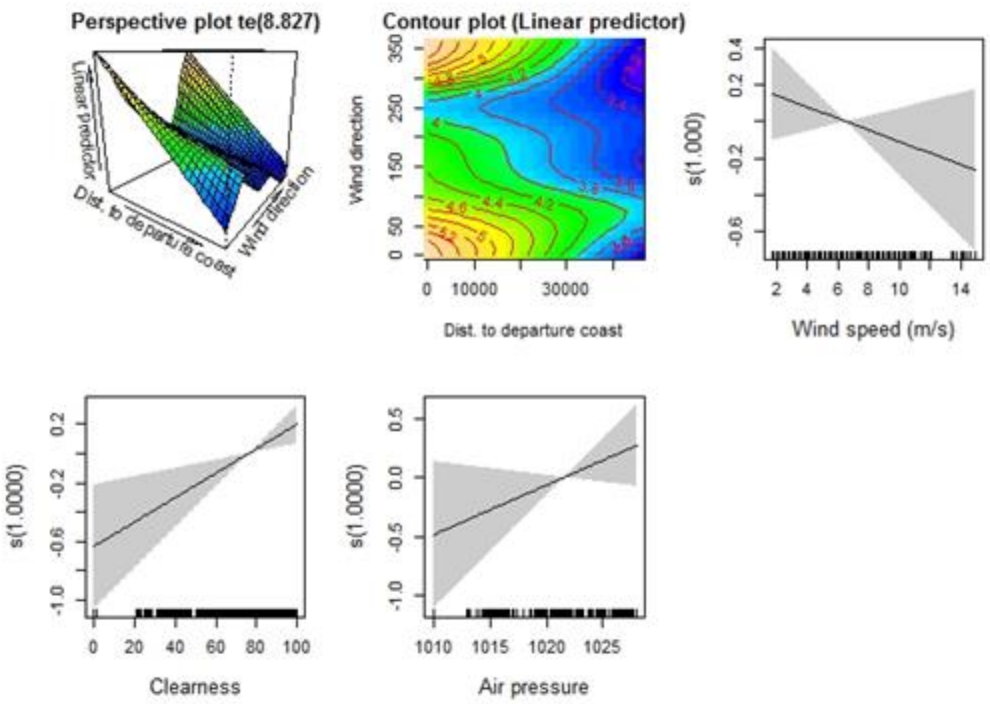


Figure 34. GAMM response curves for the Sparrowhawk. Both a perspective plot (3d) and a contour plot (2d) are shown for the interaction term (the tensor product smoother). The response is on the scale of the linear predictor. The degree of smoothing is indicated in the title of the interaction term (of the perspective plot) and in the title of the Y-axis for the 1d smooth functions. The shaded areas show the 95% Bayesian confidence intervals. Confidence intervals are not shown for the interaction term to improve interpretability.

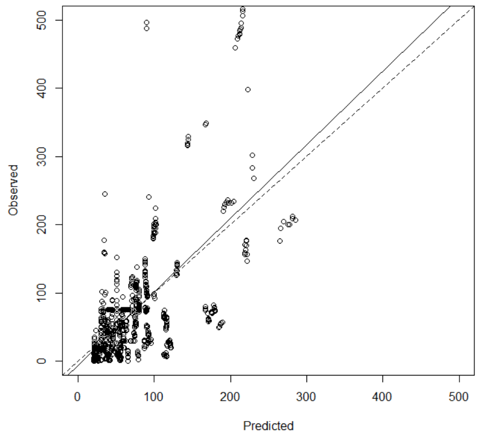


Figure 35. Split sample evaluation results: predicted average flight altitudes of Sparrowhawks against observed altitudes. The model was fitted on 70% of the tracks and was tested on 30%. The black line is a regression line based on a linear regression between observed and predicted altitudes. If the model would be perfectly calibrated all points would lie on the dashed line.

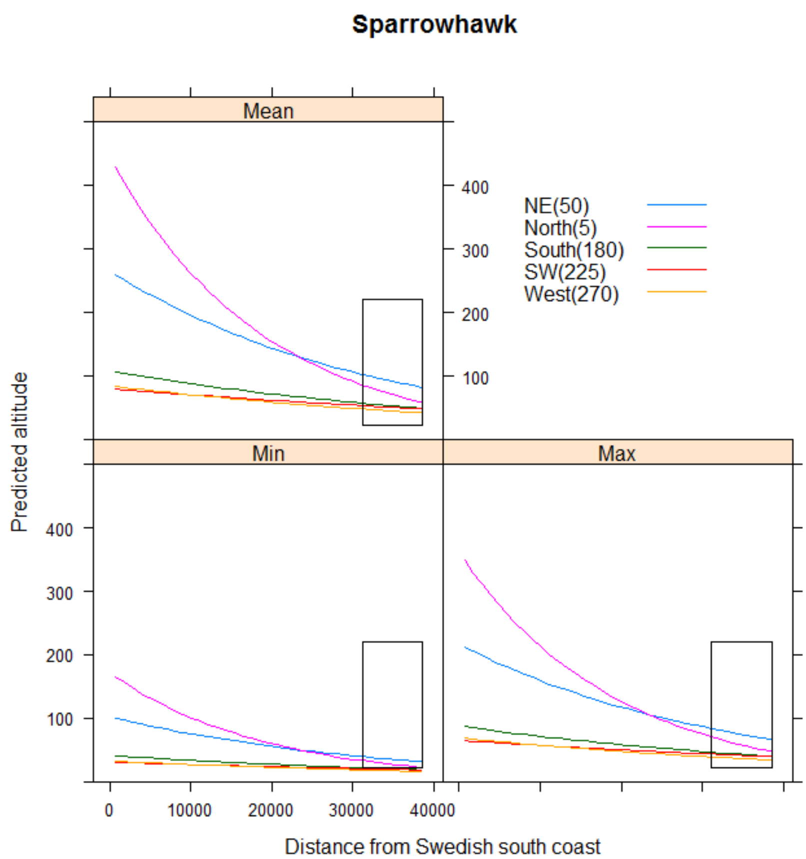


Figure 36. Average predicted altitude for Sparrowhawks in relation to distance from the coast of Sweden during different wind directions and wind speeds. All other predictor variables were set to mean values within the species specific data set. The lines are the predicted flight altitudes and the black rectangle indicates the rotor swept area by 10 MW turbines.

7.2.3 Honey Buzzard

7.2.3.1 *Spatial distribution and migration direction*

According to Karlsson et al. (2004) 7,500 Honey Buzzards (Figure 38) leave Falsterbo on an average autumn season. Based on the rangefinder data collected during the baseline at Falsterbo only 2.7% of the birds have directions indicating that they will cross the Arkona Basin, whereas the vast majority of directions from Falsterbo are concentrated around SW in the direction of Stevns Klint in Denmark (Figure 37 and Figure 39). Although some birds may leave Sweden before they reach Falsterbo the above proportion is most likely a reasonable approximation of the number of Honey Buzzards crossing, which using the mean figure from Falsterbo equals 203 birds. No figures on spring migration of raptors through the region are available.

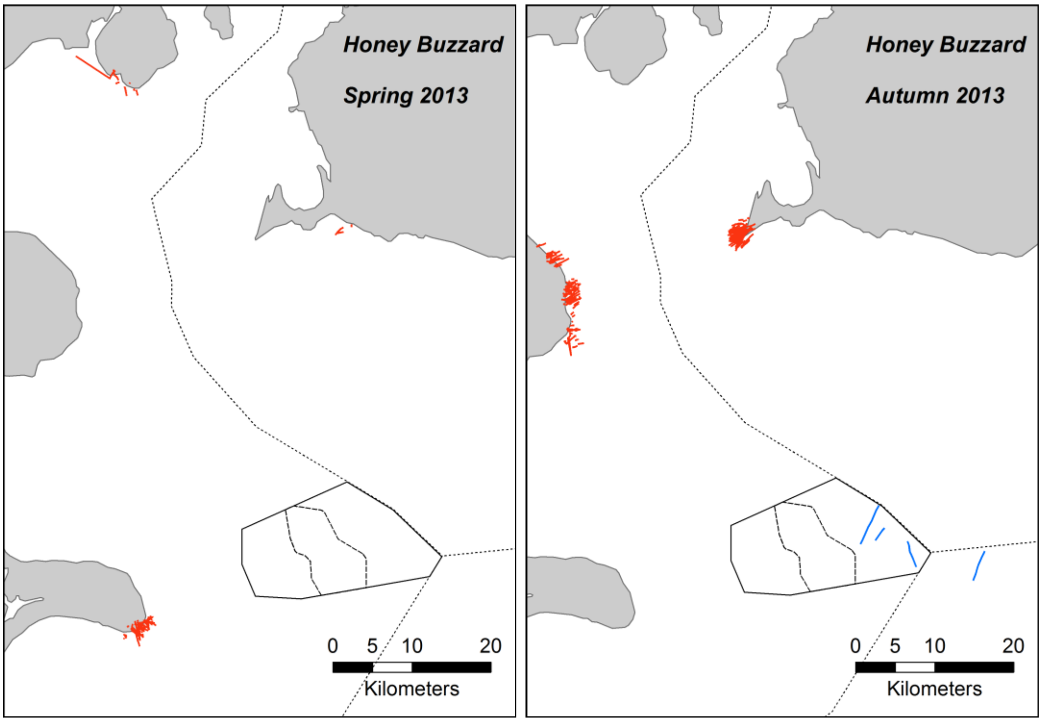


Figure 37. Migration tracks of Honey Buzzard collected in the study area, spring and autumn 2013. Radar-based tracks are marked by blue lines, and rangefinder-based tracks by red lines.

Figure 38. Honey Buzzard.

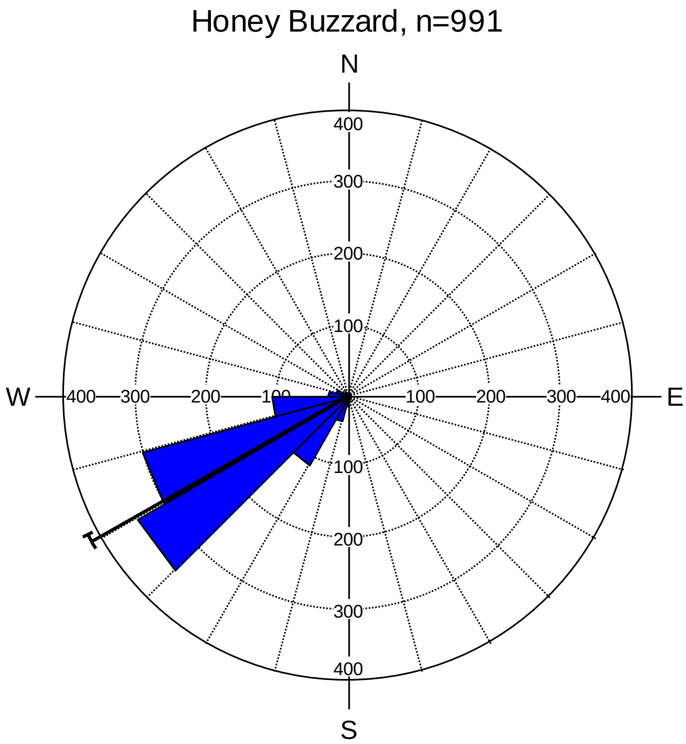


Figure 39. Sampled migration directions of Honey Buzzard at Falsterbo, autumn 2013. Numbers on the Y-axes refer to sample size (number of recordings by laser rangefinder). Each wedge represents a sector of 15°. The mean direction is indicated by the black line running from the center of the graph to the outer edge. The arcs extending to either side represent the 95% confidence limits of the mean directions.

7.2.3.2 ***Migration altitude***

The recorded flight altitudes of migrating Honey Buzzards from Sweden also show strong patterns of descend from the coast towards offshore areas. Judged from the altitude profiles the slope of descending Honey Buzzards is shallower than for Sparrowhawks. Some birds actually arrive at the Danish coast at high altitudes, yet following longer crossings over the sea almost all birds recorded at Kriegers Flak flew below 100 m (Figure 40, Figure 41). As most Honey Buzzards were recorded in head winds and cross winds, the altitude profile in tail winds is ambiguous.

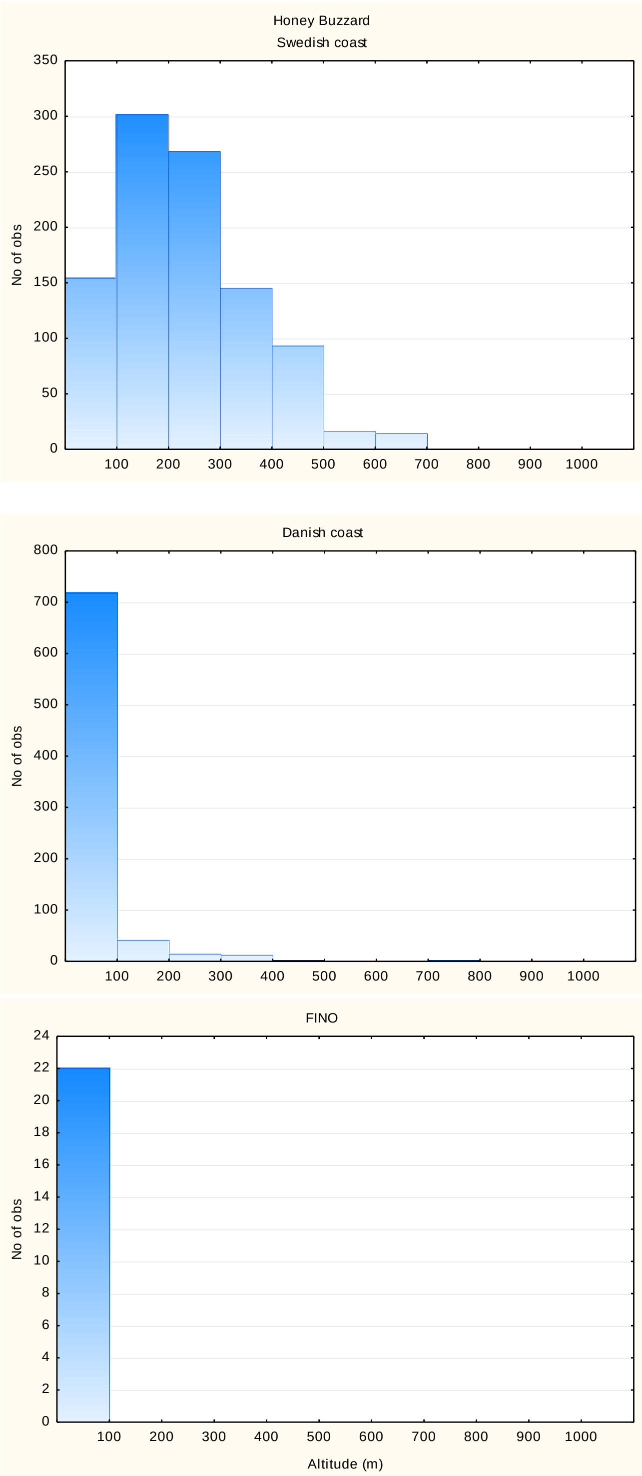


Figure 40. Frequency distribution of altitude measurements of Honey Buzzard by laser rangefinder at the Swedish south coast, at the Danish coast and at FINO 2 during autumn 2013.

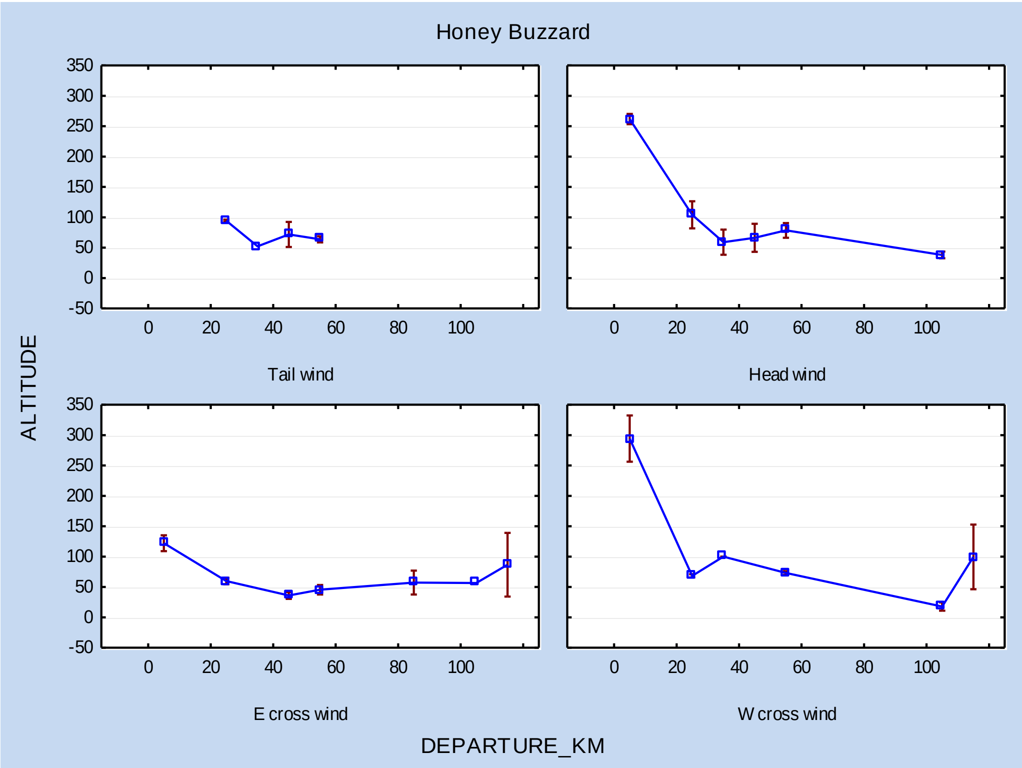


Figure 41. Changes in sampled altitude of Honey Buzzard by laser rangefinder during 2013 in relation to distance from the departure coast (north Germany in spring and south Sweden in autumn). Mean and confidence interval are given for different distances from departing coast and wind direction.

The GAMM flight model for Honey Buzzard in autumn showed that the birds fly higher in tail winds (northerly winds) in comparison to head winds and descend in altitude after leaving the coast (Figure 42). They also fly higher in lower wind speeds and increasing air pressure.

The predictive accuracy of the GAMM was high, with a good agreement between observed and predicted altitudes, a Spearman's rank correlation of 0.70, when the model was evaluated on semi-independent data (Table 15, Figure 43). The adjusted R^2 indicated also a good fit (Table 15). The model successfully accounted for the strong temporal and spatial autocorrelation in the track data by using the correlation structure and random term (serial and spatial autocorrelograms and model diagnostics are shown in Appendix A).

According to the model predictions the Honey Buzzards flew in average within rotor height of the 10 MW turbines at Kriegers Flak during all wind conditions and the differences between wind directions were minor (Figure 44). Graphs of the predictions including model standard errors are shown in the Appendix A.

Table 15. Significance and F-values for the fixed parametric (wind directions) and smooth terms included in the GAMMs for the Honey Buzzard. Adjusted R-square indicates the variance explained by the model and the Spearman's correlation coefficient the agreement between predicted and evaluated altitudes (by a split sample evaluation approach). Number of samples used in the analysis is shown on the bottom row.

		F-value	p-value
Smooth	Distance to coast: Wind direction	15.894	<0.01
	Wind speed 200 m	5.061	0.02
	Air pressure	1.384	0.24
R-sq. (adj)		0.55	
Spearman's corr.		0.70	
N of tracks (samples)		165 (1566)	

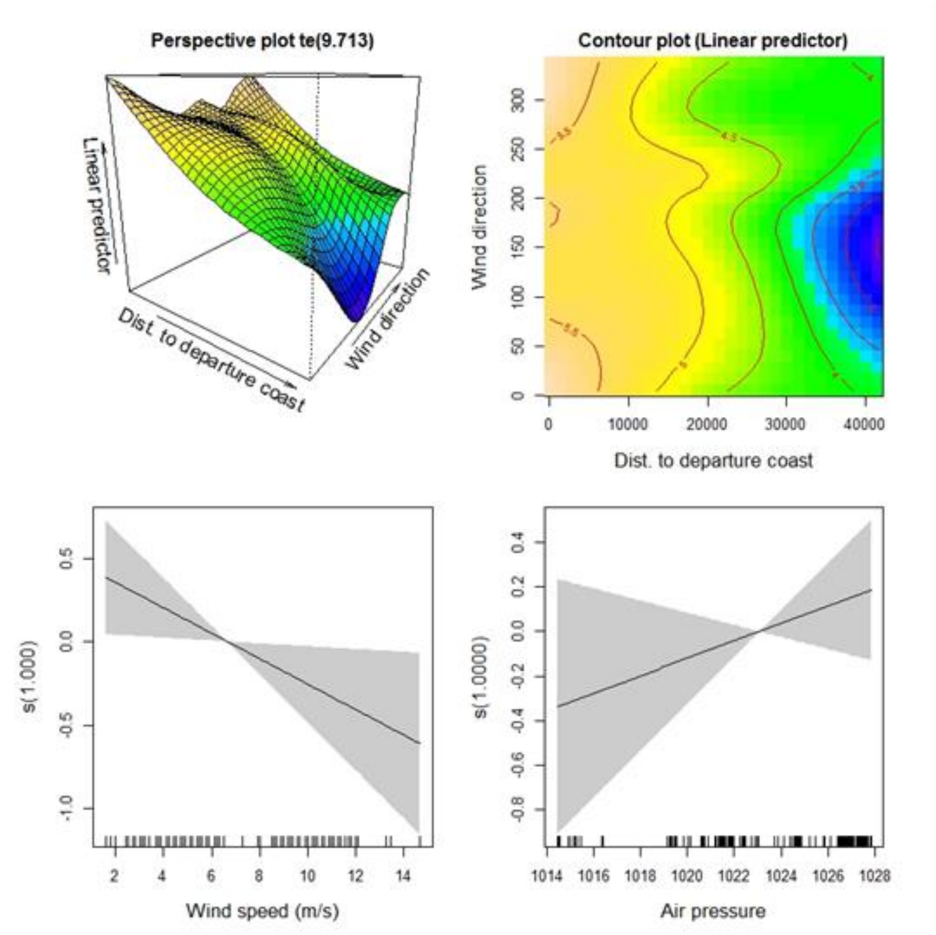


Figure 42. GAMM response curves for the Honey Buzzard. Both a perspective plot (3d) and a contour plot (2d) are shown for the interaction term (the tensor product smoother). The response is on the scale of the linear predictor. The degree of smoothing is indicated in the title of the interaction term (of the perspective plot) and in the title of the Y-axis for the 1d smooth functions. The shaded areas show the 95% Bayesian confidence intervals. Confidence intervals are not shown for the interaction term to improve interpretability.

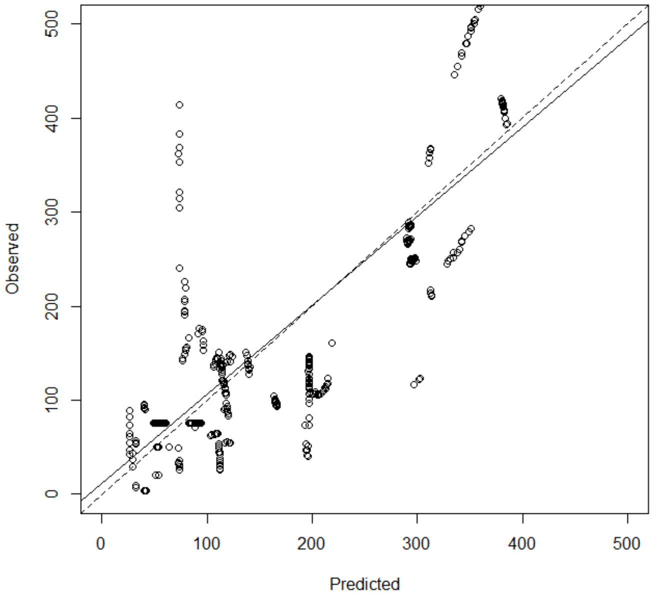


Figure 43. Split sample evaluation results: predicted average flight altitudes of Honey Buzzards against observed altitudes. The model was fitted on 70% of the tracks and was tested on 30%. The black line is a regression line based on a linear regression between observed and predicted altitudes. If the model would be perfectly calibrated all points would lie on the dashed line.

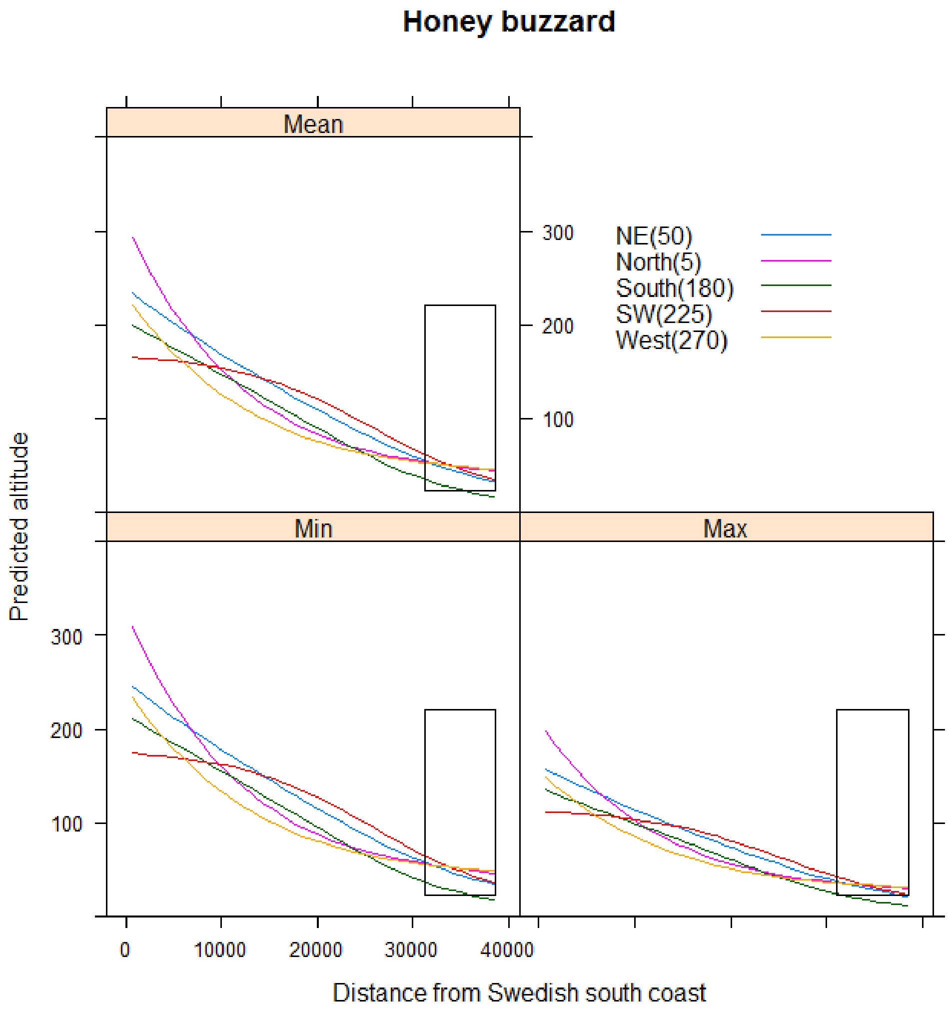


Figure 44. Average predicted altitude for Honey Buzzards in relation to distance from the coast of Sweden during different wind directions and wind speeds. All other predictor variables were set to mean values within the species specific data set. The lines are the predicted flight altitudes and the black rectangle indicates the rotor swept area by 10 MW turbines.

7.2.4 Common Buzzard

7.2.4.1 *Spatial distribution and migration direction*

According to Karlsson et al. (2004) 14,000 Common Buzzards leave Falsterbo on an average autumn season. Based on the rangefinder data collected during the baseline at Falsterbo only 6% of the birds have directions indicating that they will cross the Arkona Basin, whereas the vast majority of directions are concentrated around SW in the direction of Stevns Klint in Denmark (Figure 45, Figure 46). Although some birds may leave Sweden before they reach Falsterbo the above proportion is most likely a reasonable approximation of the number of Sparrowhawks crossing, which using the mean figure from Falsterbo equals 840 birds. No figures on spring migration of raptors through the region are available, neither from this or other studies.

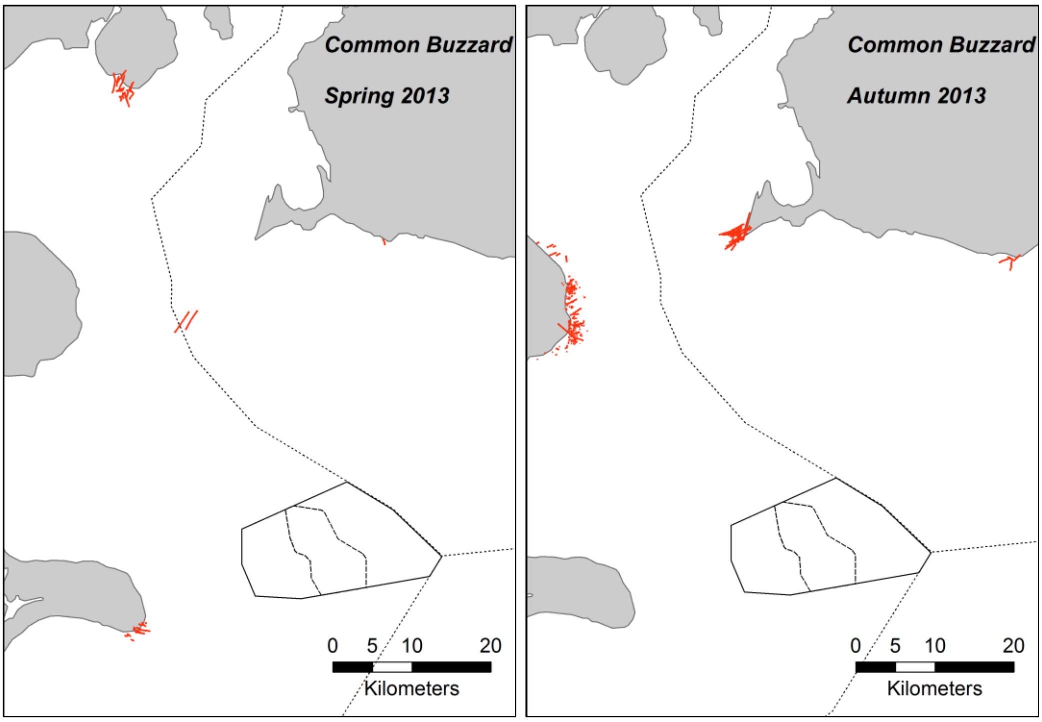


Figure 45. Migration tracks of Common Buzzard collected in the study area, spring and autumn 2013. Radar-based tracks are marked by blue lines, and rangefinder-based tracks by red lines.

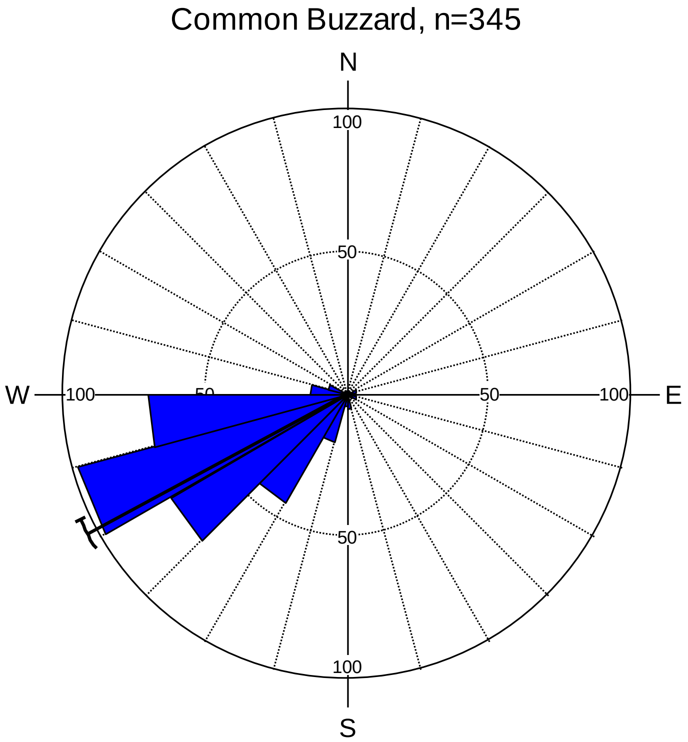


Figure 46. Sampled migration directions of Common Buzzard at Falsterbo, autumn 2013. Numbers on the Y-axes refer to sample size (number of recordings by laser rangefinder). Each wedge represents a sector of 15°. The mean direction is indicated by the black line running from the center of the graph to the outer edge. The arcs extending to either side represent the 95% confidence limits of the mean directions.

7.2.4.2 ***Migration altitude***

Despite the fact no tracks of Common Buzzards were recorded from the FINO 2 platform, the frequencies and altitude profiles of Common Buzzards obtained from Swedish and Danish coasts show similar descending trends as seen for other raptors (Figure 47, Figure 48). The high mean altitude at 20 km distance from the Swedish coast during westerly cross wind is due to a large number of tracks recorded at Stevns on the 15th October when no observations were undertaken at Falsterbo.

The angle of descend is significantly different during different wind directions with the steepest angle in tail winds when birds often initiate migration at higher altitudes (Table 16, Figure 48).

Table 16. Results of homogeneity of slope test testing whether tracks of Common Buzzaard during different wind directions have different responses of altitude to distance to land. Only the results for the interaction between wind direction and distance to land are shown for the DHI rangefinder data collected from the Swedish coast autumn 2013.

Value	F	Df	p
939692	17.11	3	< 0.00001

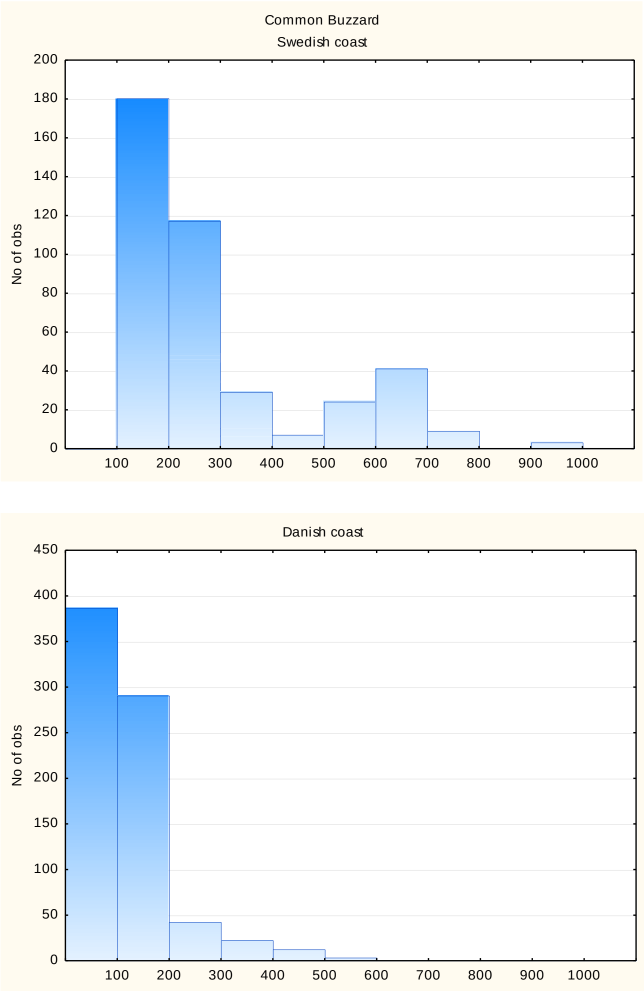


Figure 47. Frequency distribution of altitude measurements of Common Buzzard by laser rangefinder at the Swedish south coast and at the Danish coast during autumn 2013.

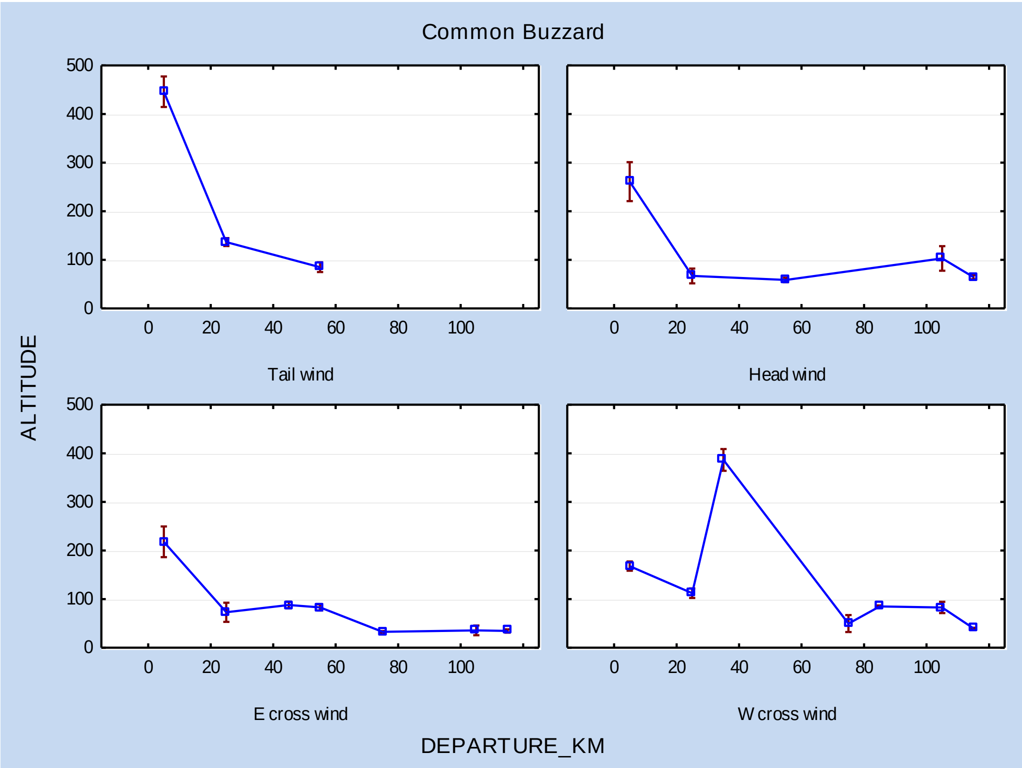


Figure 48. Changes in sampled altitude of Common Buzzard by laser rangefinder during 2013 in relation to distance from the departure coast (north Germany in spring and south Sweden in autumn). Mean and confidence interval are given for different distances from departing coast and wind direction.

The GAMM flight model for Common Buzzards indicates that the birds first ascend in altitude when leaving land where after they start descending (Figure 49). This patterns is most likely a combined effect of birds using thermals during tail winds in autumn and an artefact due to large numbers of birds being tracked at Stevns during one day of peak migration when no observations were made from the Swedish coast. The model also indicates that the Common Buzzards fly higher with decreasing wind speeds, intermediate temperature and increasing pressure. The predictive accuracy of the GAMM was high, with a good agreement between observed and predicted altitudes, a Spearman's rank correlation of 0.75, when the model was evaluated on semi-independent data (Table 17, Figure 49, Figure 50). The adjusted R^2 indicated also a good fit (Table 17). The model successfully accounted for the strong temporal and spatial autocorrelation in the track data by using the correlation structure and random term (serial and spatial autocorrelograms and model diagnostics are shown in Appendix A).

According to the model predictions the Common Buzzards flew on average within rotor height of the 10 MW turbines at Kriegers Flak during all wind directions in mean and minimum weather conditions. According to the predictions the birds flew very low in maximum weather conditions, even below rotor high which might be an underestimation since there are no observations from Kriegers Flak (Figure 51). Graphs of the predictions including model standard errors are shown in the Appendix A.

Table 17. Significance and t-values for the fixed parametric (wind directions) and smooth terms included in the GAMMs for the Common Buzzard. Adjusted R-square indicates the variance explained by the model and the Spearman's correlation coefficient the agreement between predicted and evaluated altitudes (by a split sample evaluation approach). Number of samples used in the analysis is shown on the bottom row.

		t-value	**p-value**
Parametric	Tail wind		
	Head wind	-0.887	0.38
	Cross wind E	-0.250	0.80
	Cross wind W	-0.753	0.45
Smooth		**F-value**	**p-value**
	Distance to departure coast	42.501	<0.01
	Wind speed	4.169	<0.05
	Temperature	2.479	0.09
	Pressure	0.469	0.49
R-sq. (adj)		0.40	
Spearman's corr.		0.75	
N of tracks (samples)		230 (1065)	

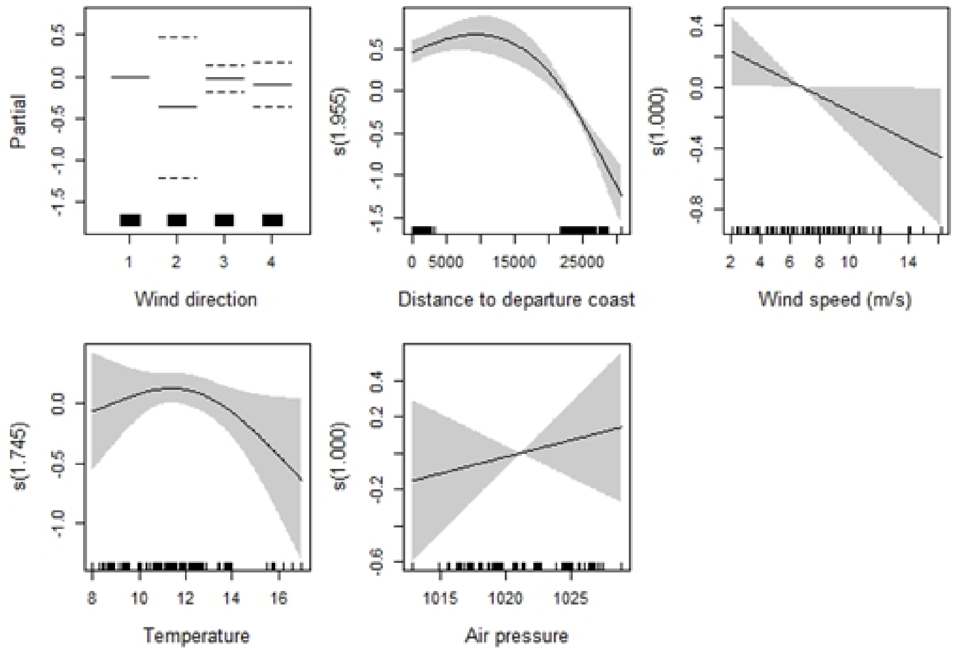


Figure 49. GAMM response curves for the Common Buzzard. The values of the environmental predictors are shown on the X-axis and the response on the Y-axis is on the scale of the linear predictor. The degree of smoothing is indicated in the title of the Y-axis. The shaded areas and the dotted lines show the 95% Bayesian confidence intervals.

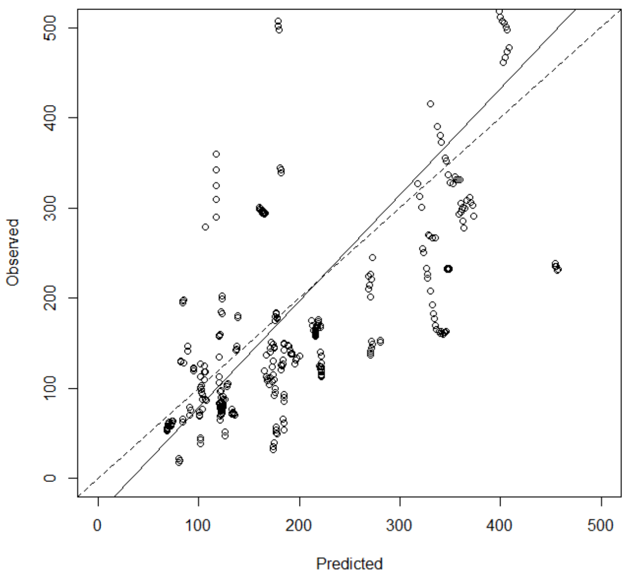


Figure 50. Split sample evaluation results: predicted average flight altitudes of Common Buzzards against observed altitudes. The model was fitted on 70% of the tracks and was tested on 30%. The black line is a regression line based on a linear regression between observed and predicted altitudes. If the model would be perfectly calibrated all points would lie on the dashed line.

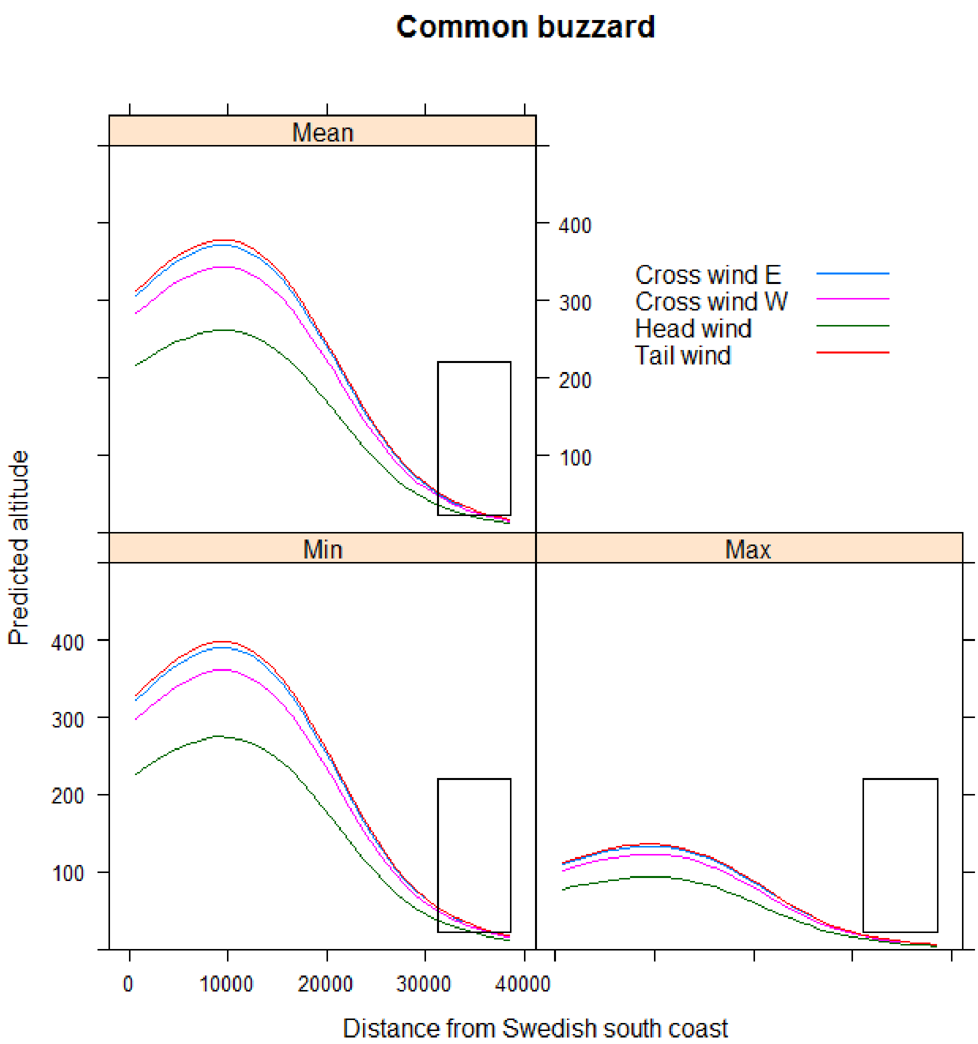


Figure 51. Average predicted altitude for Common Buzzards in relation to distance from the coast of Sweden during different wind directions and wind speeds. All other predictor variables are set to mean values within the species specific data set. The lines are the predicted flight altitudes and the black rectangle indicates the rotor swept area by 10 MW turbines.

7.2.5 Rough-legged Buzzard

7.2.5.1 *Spatial distribution and migration direction*

According to Karlsson et al. (2004) 930 Rough-legged Buzzards leave Falsterbo on an average autumn season. Based on the rangefinder data collected during the baseline at Falsterbo 13% of the birds have directions indicating that they will cross the Arkona Basin, whereas the majority of directions are concentrated around SW in the direction of Stevns Klint in Denmark (Figure 52, Figure 53). Although some birds may leave Sweden before they reach Falsterbo the above proportion is most likely a reasonable approximation of the number of Rough-legged Buzzards crossing, which using the mean figure from Falsterbo equals 121 birds. No figures on spring migration of raptors through the region are available, neither from this or other studies.

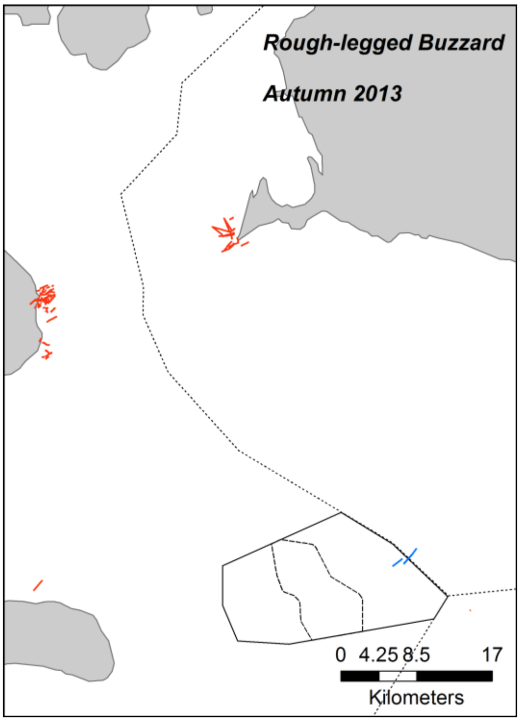


Figure 52. Migration tracks of Rough-legged Buzzard collected in the study area, autumn 2013. Radar-based tracks are marked by blue lines, and rangefinder-based tracks by red lines.

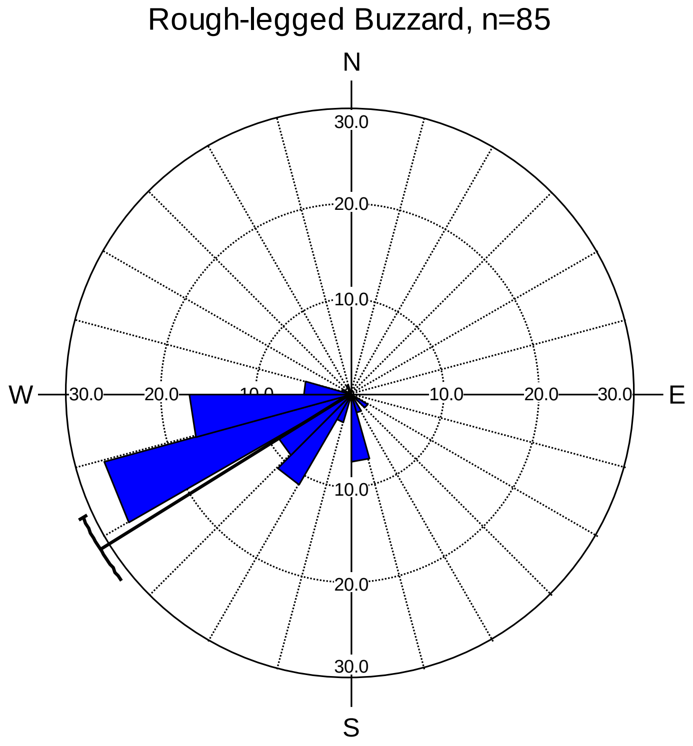


Figure 53. Sampled migration directions of Rough-legged Buzzard at Falsterbo, autumn 2013. Numbers on the Y-axes refer to sample size (number of recordings by laser rangefinder). Each wedge represents a sector of 15°. The mean direction is indicated by the black line running from the centre of the graph to the outer edge. The arcs extending to either side represent the 95% confidence limits of the mean direction.

7.2.5.2 *Migration altitude*

The patterns of flight altitude displayed by migrating Rough-legged Buzzards are similar to other medium-sized raptors showing a descend from the Swedish coast which results in 60% flying above 200 m as they leave the Swedish coast, as compared to 40% at arrival to the Danish coast and 0% at Kriegers Flak (Figure 54, Figure 55). In fact, all birds recorded at FINO 2 flew at altitudes below 100 m.

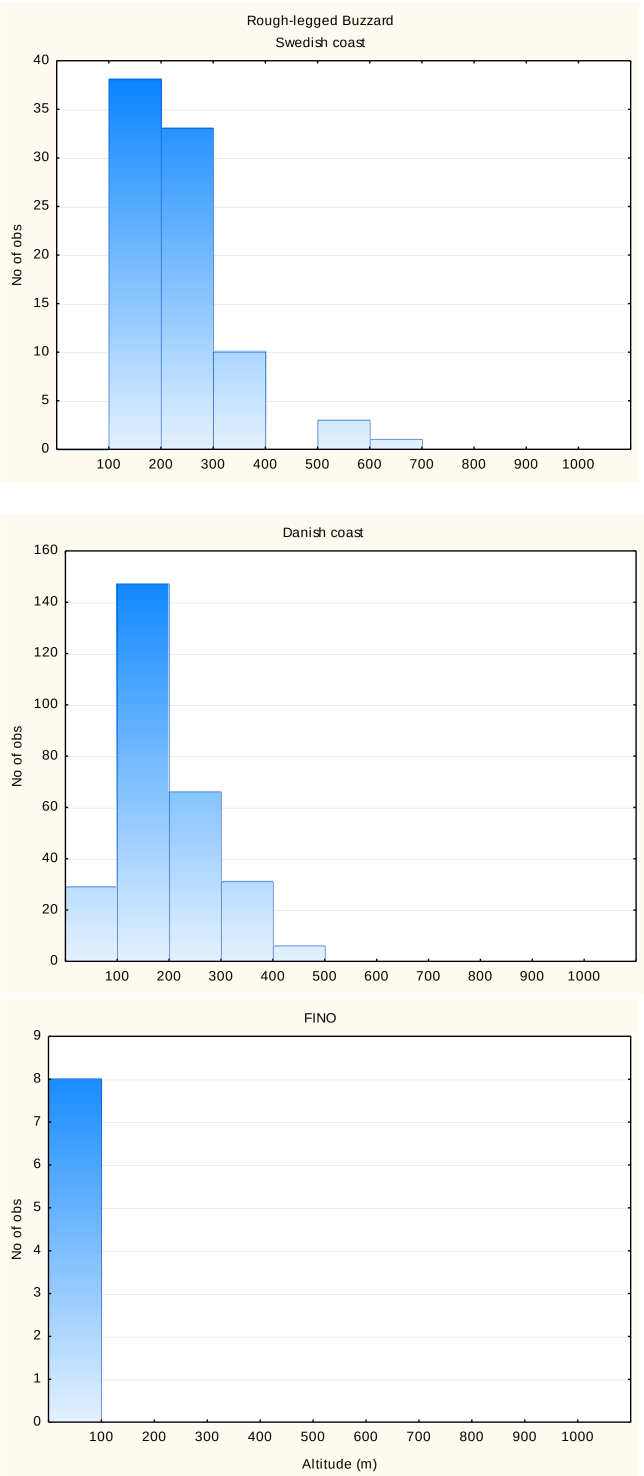


Figure 54. Frequency distribution of altitude measurements of Rough-legged Buzzard by laser rangefinder at the Swedish south coast, at the Danish coast and at FINO 2 during autumn 2013.

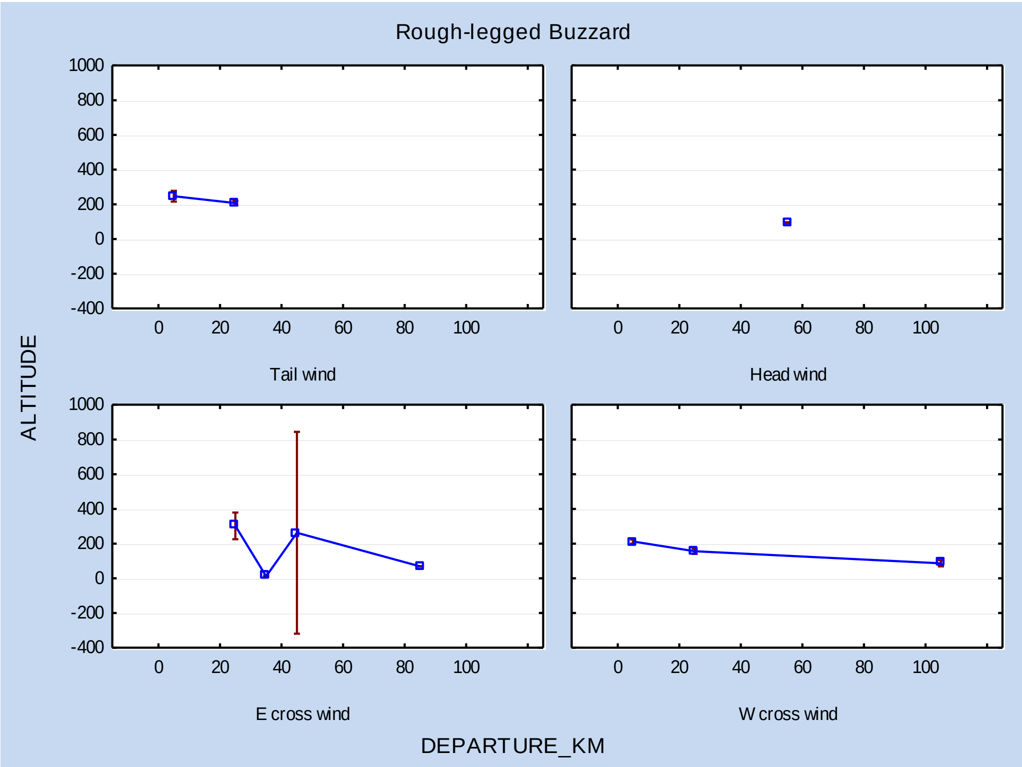


Figure 55. Changes in sampled altitude of Rough-legged Buzzard by laser rangefinder during 2013 in relation to distance from the departure coast (north Germany in spring and south Sweden in autumn). Mean and confidence interval are given for different distances from departing coast and wind direction.

7.2.6 **Red Kite**

7.2.6.1 ***Spatial distribution and migration direction***

According to Karlsson et al. (2004) 500 Red Kites (Figure 57) leave Falsterbo on an average autumn season. Based on the rangefinder data collected during the baseline at Falsterbo 12% of the birds have directions indicating that they will cross the Arkona Basin, whereas the vast majority of directions are concentrated around SW in the direction of Stevns Klint in Denmark (Figure 56, Figure 58). Although some birds may leave Sweden before they reach Falsterbo the above proportion is most likely a reasonable approximation of the number of Red Kites crossing, which using the mean figure from Falsterbo equals 60 birds. No figures on spring migration of raptors through the region are available, neither from this or other studies.

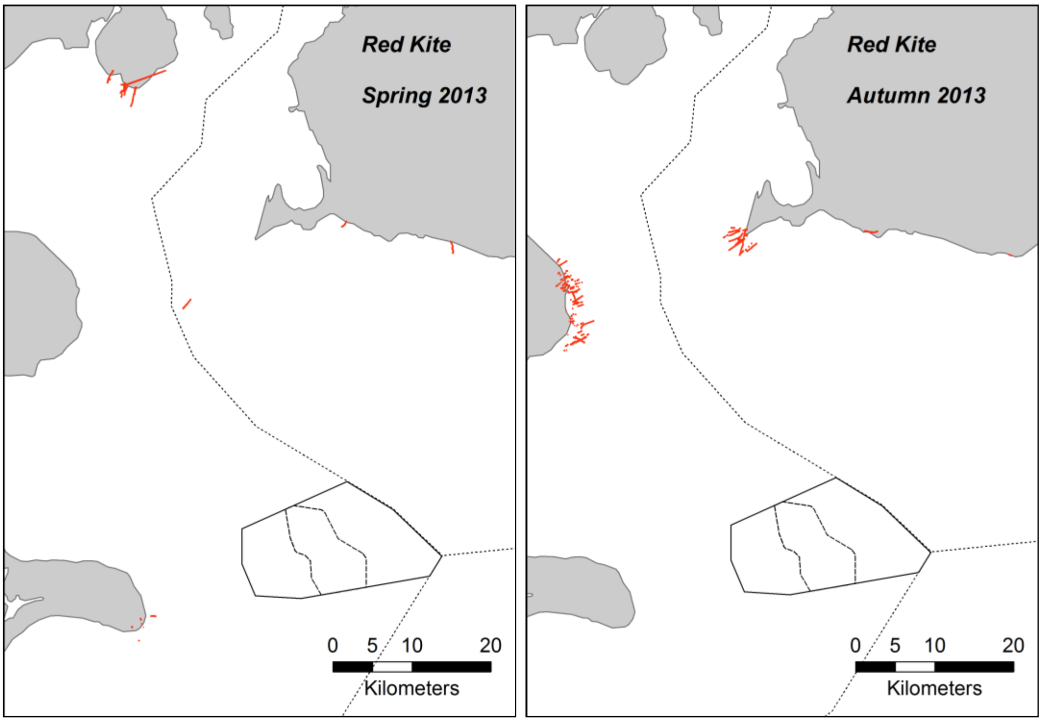


Figure 56. Migration tracks of Red Kite collected in the study area, spring and autumn 2013. Radar-based tracks are marked by blue lines, and rangefinder-based tracks by red lines.

Figure 57. Red Kite.

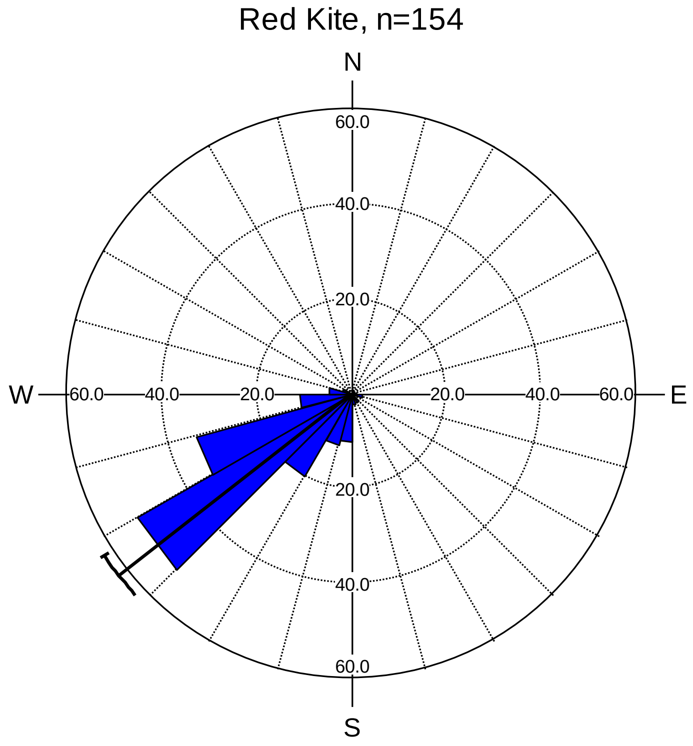


Figure 58. Sampled migration directions of Red Kite at Falsterbo, autumn 2013. Numbers on the Y-axes refer to sample size (number of recordings by laser rangefinder). Each wedge represents a sector of 15°. The mean direction is indicated by the black line running from the centre of the graph to the outer edge. The arcs extending to either side represent the 95% confidence limits of the mean direction.

7.2.6.2 ***Migration altitude***

Migrating Red Kites show typical patterns of flight altitude with a wide range of altitudes as the birds leave Falsterbo as compared to the arrival coasts in Denmark (Figure 59, Figure 60). Too few records of kites were made on FINO 2 to allow for computation of frequency distribution. The angle of descend in Red Kites seems to be quite shallow, yet beyond 20 km from the Swedish most if not all birds fly below 200 m altitude (Figure 60). The angles of descend differ significantly during different wind directions (Table 18).

Table 18. Results of homogeneity of slope test testing whether tracks of Red Kite during different wind directions have different responses of altitude to distance to land. Only the results for the interaction between wind direction and distance to land are shown for the DHI rangefinder data collected from the Swedish coast autumn 2013.

Value	F	Df	p
279081	5.40	3	< 0.005

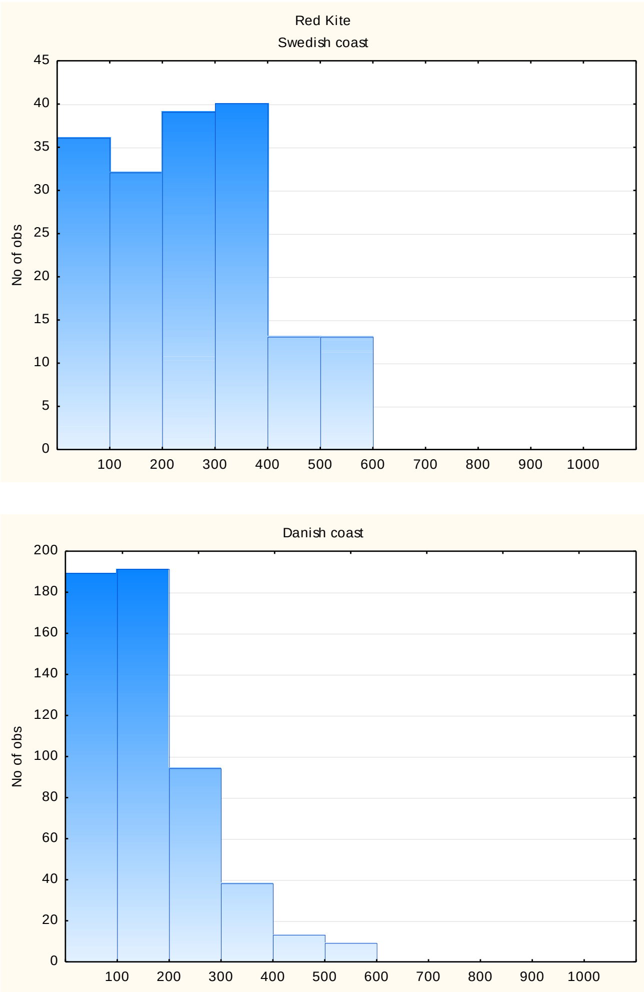


Figure 59. Frequency distribution of altitude measurements of Red Kite by laser rangefinder at the Swedish south coast and at the Danish coast during autumn 2013.

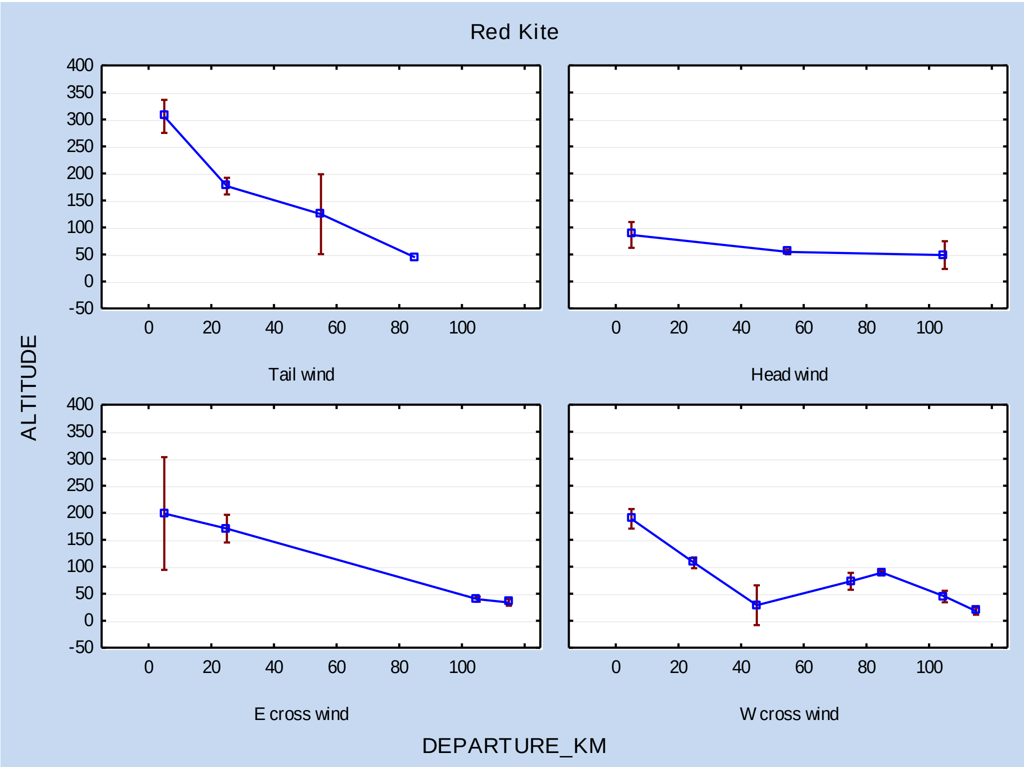


Figure 60. Changes in sampled altitude of Red Kite by laser rangefinder during 2013 in relation to distance from the departure coast (north Germany in spring and south Sweden in autumn). Mean and confidence interval are given for different distances from departing coast and wind direction.

The GAMM flight model for Red Kite in autumn indicates that the birds flew higher in tail winds (northerly winds) and first ascend in altitude after leaving the coast, but further offshore start descending again (Figure 61). The predictive accuracy of the GAMM was high, with a good agreement between observed and predicted altitudes, a Spearman's rank correlation of 0.72, when the model was evaluated on semi-independent data (Table 19, Figure 62). The adjusted R^2 indicated a reasonable fit (Table 19). The model successfully accounted for the strong temporal and spatial autocorrelation in the track data by using the correlation structure and random term (serial and spatial autocorrelograms and model diagnostics are shown in Appendix A).

According to the predictions the birds flew on average below rotor height of the 10 MW turbines during all wind conditions (Figure 63). However, as observation are recorded only within about 25 km from the departure coast, the predictions are most likely under-estimations and the flight altitudes at the wind farm could be expected to be close to the predicted altitude at about 25 km from the departure coast (rotor height, Figure 63). Graphs of the predictions including model standard errors are shown in the Appendix A.

Table 19. Significance and F-values for the fixed parametric (wind directions) and smooth terms included in the GAMMs for the Red Kite. Adjusted R-square indicates the variance explained by the model and the Spearman's correlation coefficient the agreement between predicted and evaluated altitudes (by a split sample evaluation approach). Number of samples used in the analysis is shown on the bottom row.

		F-value	p-value
Smooth	Distance to coast: Wind direction	24.565	<0.01
	Clearness	2.993	0.07
R-sq. (adj)		0.28	
Spearman's corr.		0.72	
N of tracks (samples)		151 (574)	

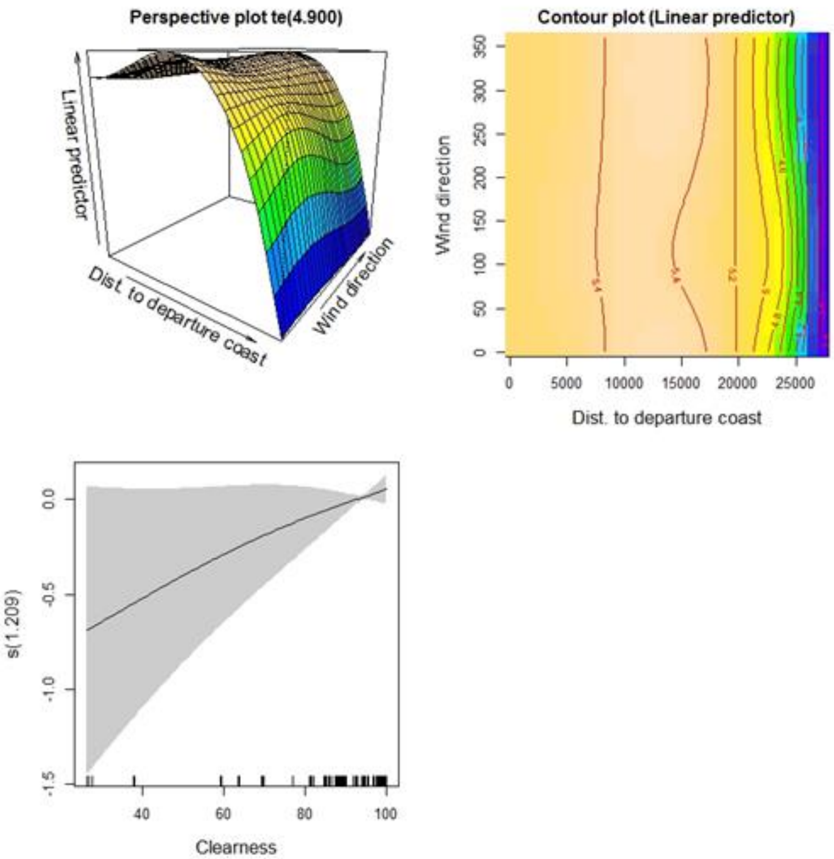


Figure 61. GAMM response curves for the Red Kite. Both a perspective plot (3d) and a contour plot (2d) are shown for the interaction term (the tensor product smoother). The response is on the scale of the linear predictor. The degree of smoothing is indicated in the title of the interaction term (of the perspective plot) and in the title of the Y-axis for the 1d smooth functions. The shaded areas show the 95% Bayesian confidence intervals. Confidence intervals are not shown for the interaction term to improve interpretability.

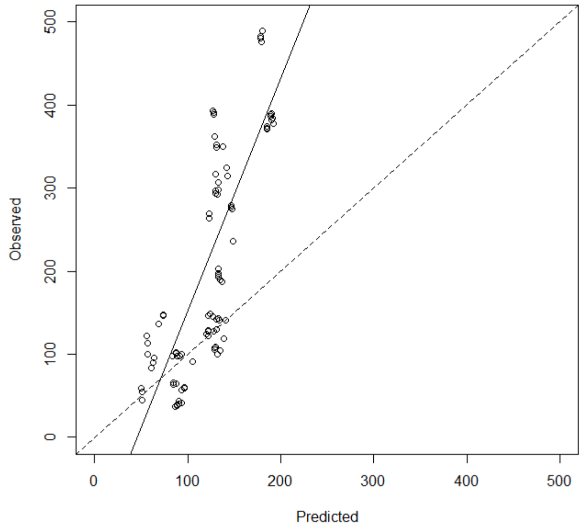


Figure 62. Split sample evaluation results: predicted average flight altitudes of Red Kites against observed altitudes. The model was fitted on 70% of the tracks and was tested on 30%. The black line is a regression line based on a linear regression between observed and predicted altitudes. If the model would be perfectly calibrated all points would lie on the dashed line.

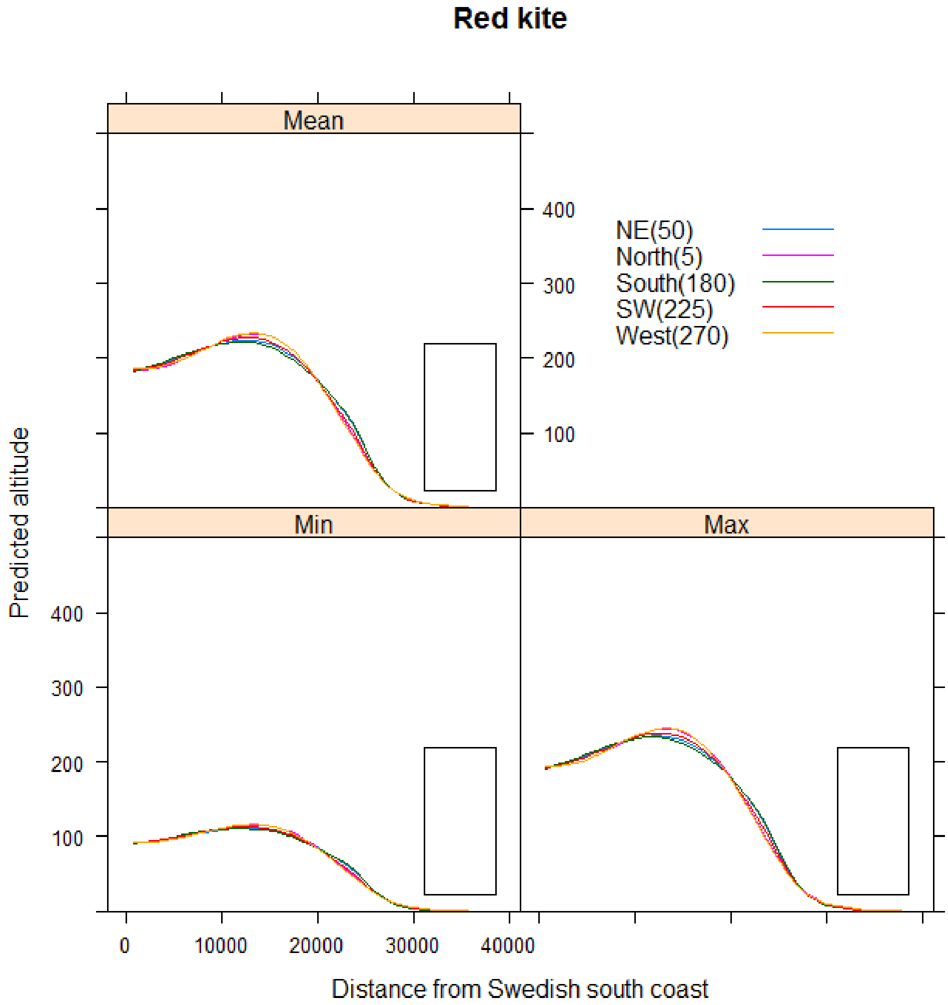


Figure 63. Average predicted altitude for Red Kites in relation to distance from the coast of Sweden during different wind directions and wind speeds. All other predictor variables were set to mean values within the species specific data set. The lines are the predicted flight altitudes and the black rectangle indicates the rotor swept area by 10 MW turbines.

7.2.7 **Osprey**

7.2.7.1 ***Spatial distribution and migration direction***

According to Karlsson et al. (2004) 241 Ospreys leave Falsterbo on an average autumn season. Based on the rangefinder data collected during the baseline at Falsterbo 17% of the birds have directions indicating that they will cross the Arkona Basin, whereas the majority of directions are concentrated around SW in the direction of Stevns Klint in Denmark (Figure 64, Figure 65). Although some birds may leave Sweden before they reach Falsterbo the above proportion is most likely a reasonable approximation of the number of Ospreys crossing, which using the mean figure from Falsterbo equals 40 birds. No figures on spring migration of raptors through the region are available, neither from this or other studies.

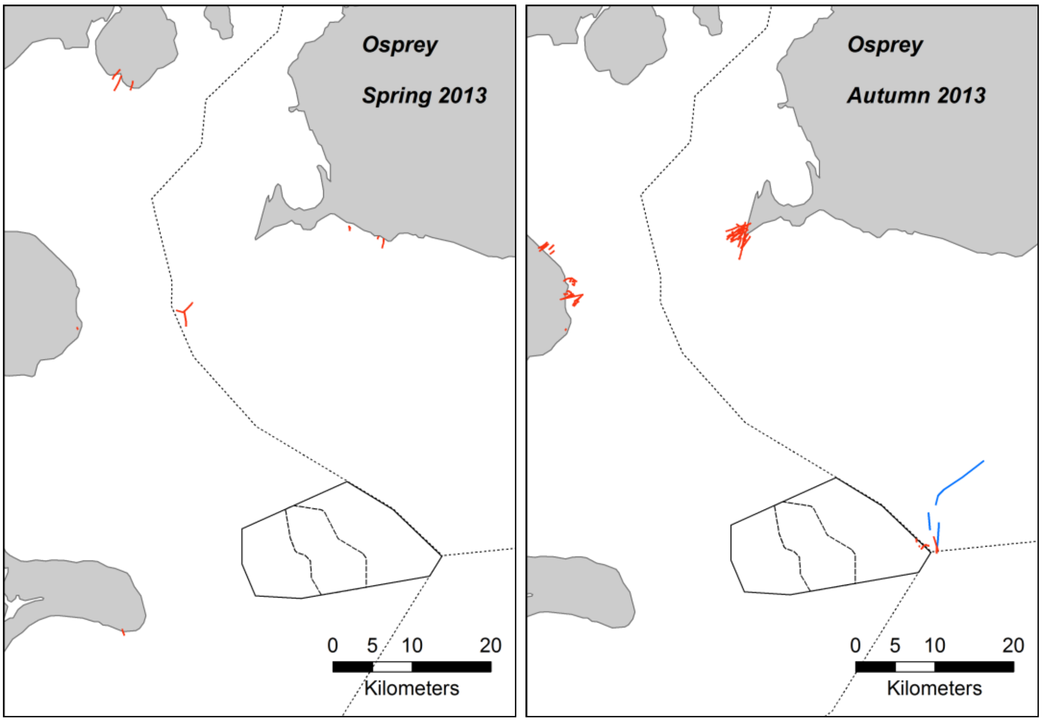


Figure 64. Migration tracks of Osprey collected in the study area, spring and autumn 2013. Radar-based tracks are marked by blue lines, and rangefinder-based tracks by red lines.

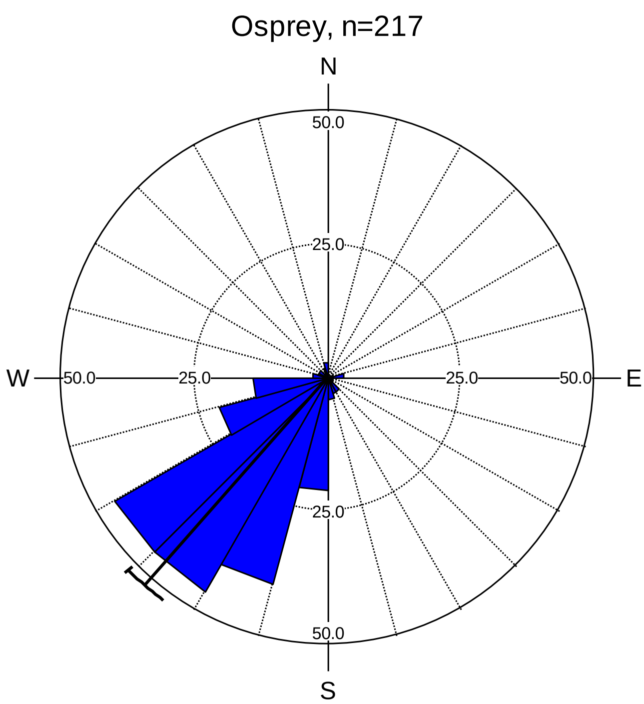


Figure 65. Sampled migration directions of Osprey at Falsterbo, autumn 2013. Numbers on the Y-axes refer to sample size (number of recordings by laser rangefinder). Each wedge represents a sector of 15°. The mean direction is indicated by the black line running from the centre of the graph to the outer edge. The arcs extending to either side represent the 95% confidence limits of the mean direction.

7.2.7.2 *Migration altitude*

Although Ospreys show a tendency for descending migration altitude as they leave the Swedish coast the angle of descend is quite shallow as most of the birds recorded near the Swedish coast actually fly below 200 m (Figure 66, Figure 67).

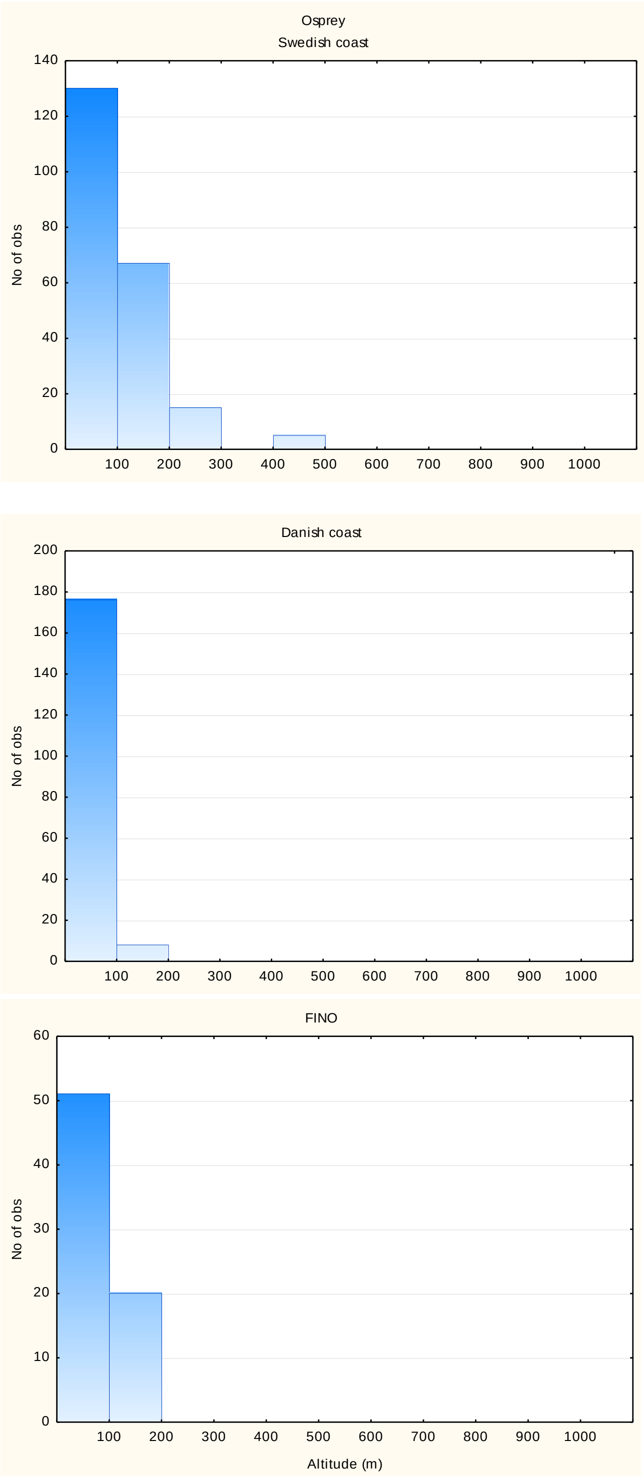


Figure 66. Frequency distribution of altitude measurements of Osprey by laser rangefinder at the Swedish south coast, at the Danish coast and at FINO 2 during autumn 2013.

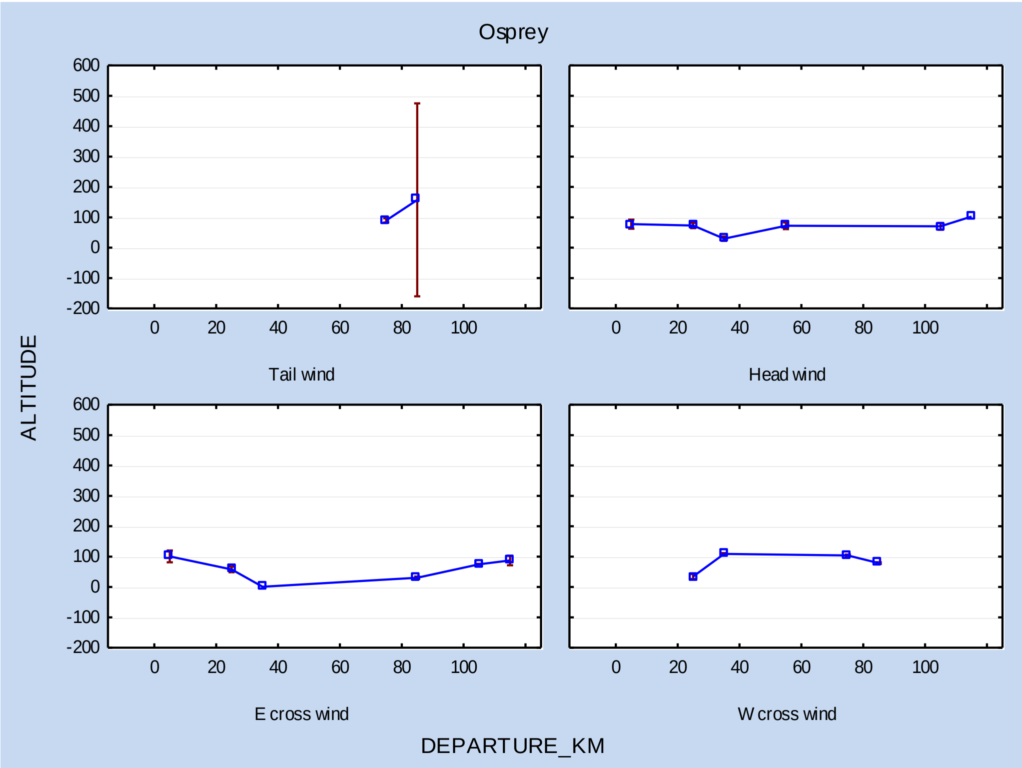


Figure 67. Changes in sampled altitude of Osprey by laser rangefinder during 2013 in relation to distance from the departure coast (north Germany in spring and south Sweden in autumn). Mean and confidence interval are given for different distances from departing coast and wind direction.

7.2.8 White-tailed Eagle

7.2.8.1 *Spatial distribution and migration direction*

Only very few tracks of White-tailed Eagle (Figure 68) were obtained, and all from the coasts of Denmark and Sweden (Figure 69). The low sample did not allow for statistical analyses of the data.

Figure 68. White-tailed Eagle.

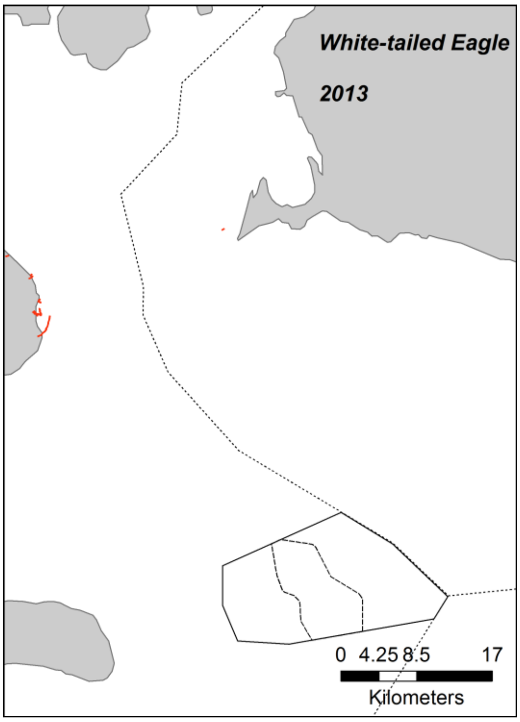


Figure 69. Migration tracks of White-tailed Eagle collected in the study area, spring and autumn 2013. Radar-based tracks are marked by blue lines, and rangefinder-based tracks by red lines.

7.2.9 Hen Harrier

7.2.9.1 *Spatial distribution and migration direction*

According to Karlsson et al. (2004) 280 Hen Harriers leave Falsterbo on an average autumn season. Based on the rangefinder data collected during the baseline at Falsterbo 37% of the birds have directions indicating that they will cross the Arkona Basin (Figure 70). It should be noted, however, that this proportion is based on a sample of only 17 rangefinder recordings. Using the mean figure from Falsterbo, the number crossing equals 104 birds. No figures on spring migration of raptors through the region are available, neither from this or other studies.

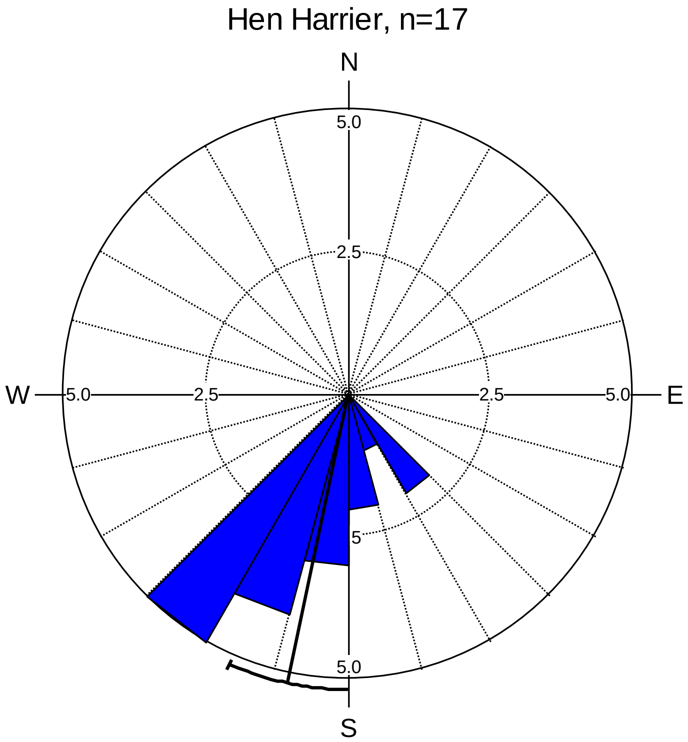


Figure 70. Sampled migration directions of Hen Harrier at Falsterbo, autumn 2013. Numbers on the Y-axes refer to sample size (number of recordings by laser rangefinder). Each wedge represents a sector of 15°. The mean direction is indicated by the black line running from the centre of the graph to the outer edge. The arcs extending to either side represent the 95% confidence limits of the mean direction.

7.2.9.2 *Migration altitude*

Migrating Hen Harriers show similar descending trends of flight altitudes from the Swedish coast as buzzards (Figure 71, Figure 72), and at distances beyond 20 km from the coast they fly below 200 m. The descend seems to be particularly steep in tail winds when birds often initiate migration at higher altitudes (Figure 72).

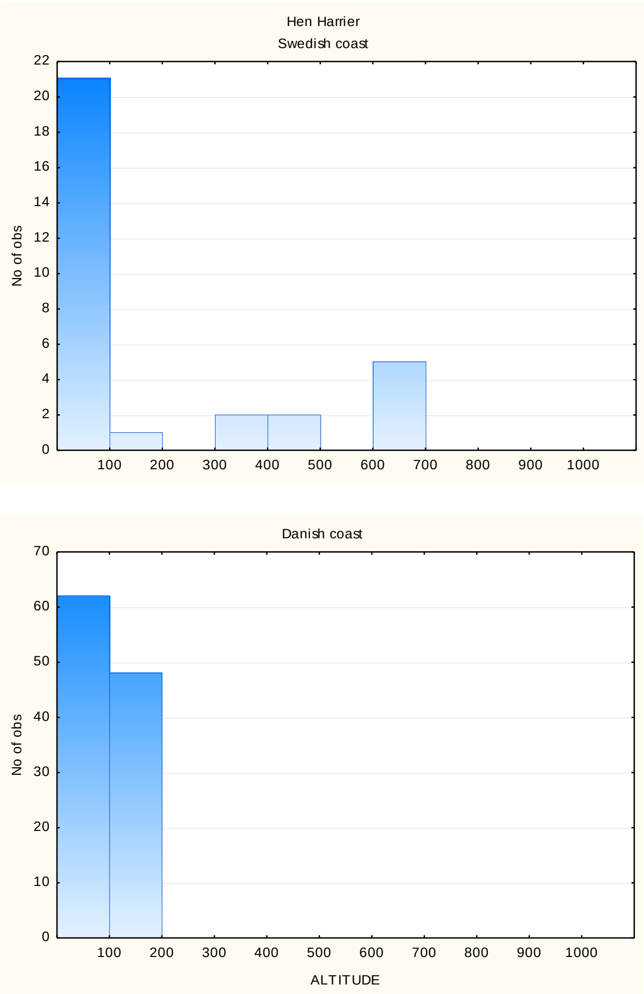


Figure 71. Frequency distribution of altitude measurements of Hen Harrier by laser rangefinder at the Swedish south coast and at the Danish coast during autumn 2013.

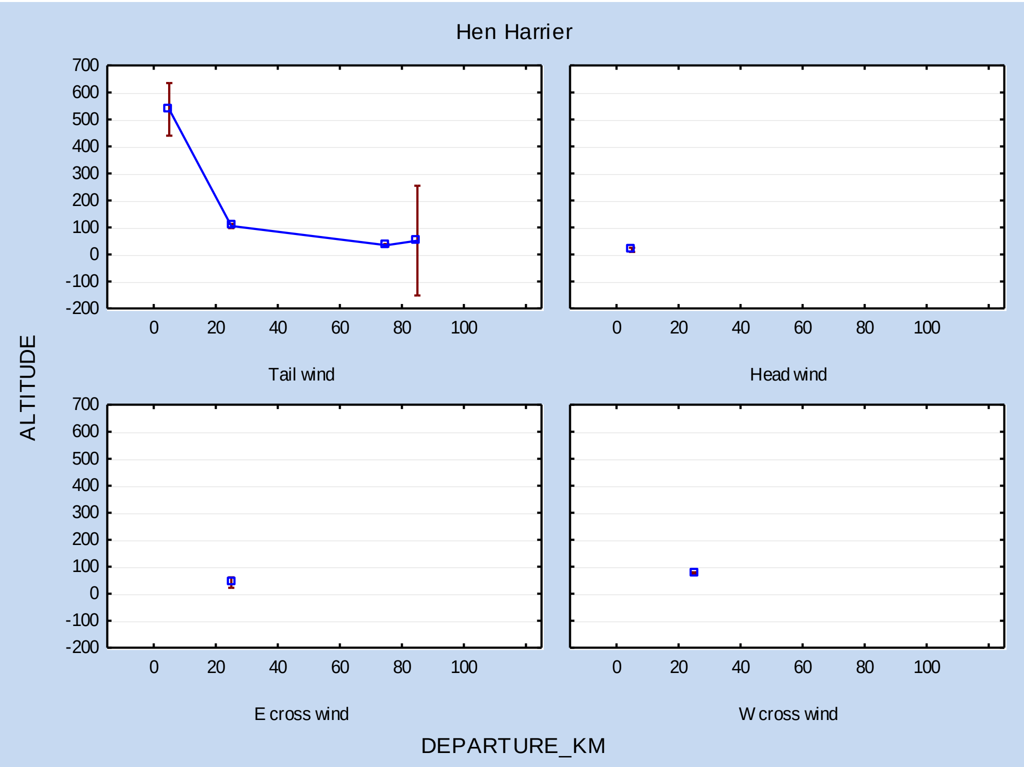


Figure 72. Changes in sampled altitude of Hen Harrier by laser rangefinder during 2013 in relation to distance from the departure coast (north Germany in spring and south Sweden in autumn). Mean and confidence interval are given for different distances from departing coast and wind direction.

7.2.10 **Marsh Harrier**

7.2.10.1 ***Spatial distribution and migration direction***

According to Karlsson et al. (2004) 550 Marsh Harriers leave Falsterbo on an average autumn season. Based on the rangefinder data collected during the baseline at Falsterbo 9% of the birds have directions indicating that they will cross the Arkona Basin, whereas the vast majority of directions are concentrated around SW in the direction of Stevns Klint in Denmark (Figure 73, Figure 74). Although some birds may leave Sweden before they reach Falsterbo the above proportion is most likely a reasonable approximation of the number of Marsh Harriers crossing, which using the mean figure from Falsterbo equals 50 birds. No figures on spring migration of raptors through the region are available, neither from this or other studies.

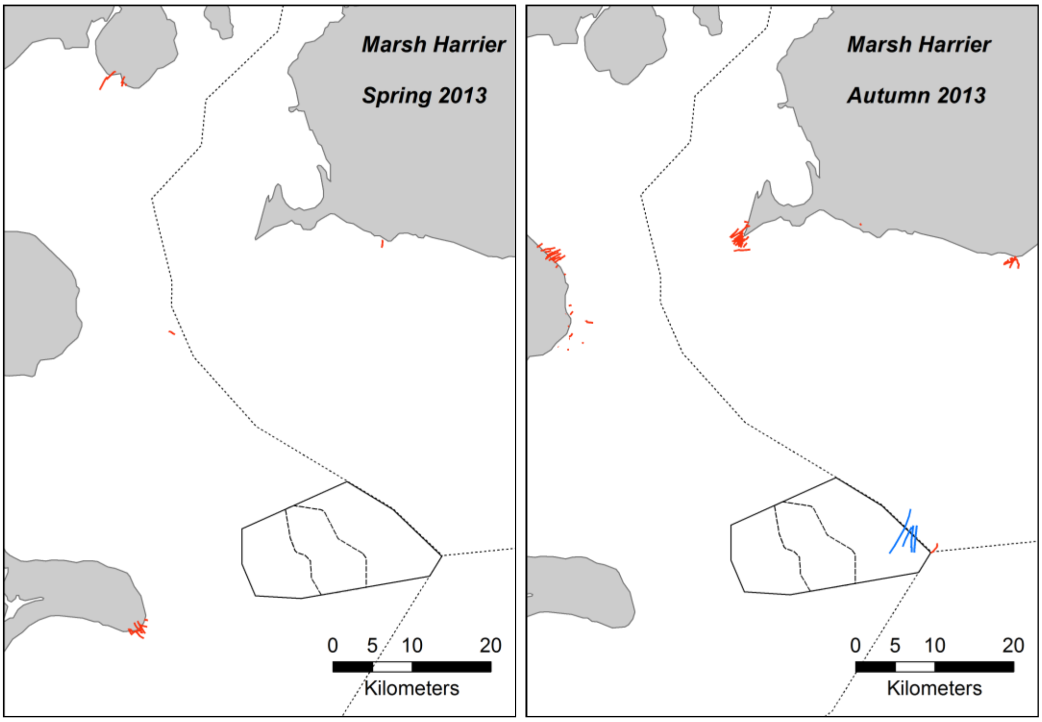


Figure 73. Migration tracks of Marsh Harrier collected in the study area, spring and autumn 2013. Radar-based tracks are marked by blue lines, and rangefinder-based tracks by red lines.

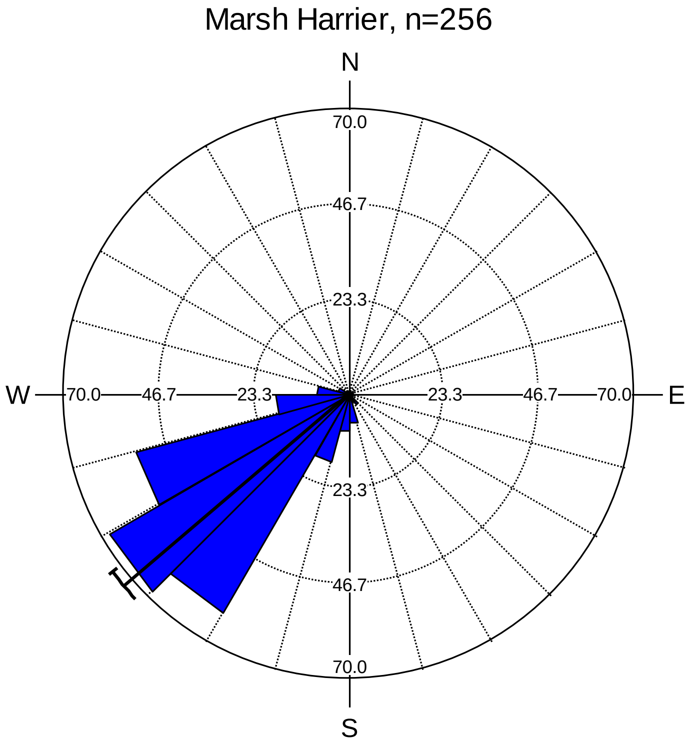


Figure 74. Sampled migration directions of Marsh Harrier at Falsterbo, autumn 2013. Numbers on the Y-axes refer to sample size (number of recordings by laser rangefinder). Each wedge represents a sector of 15°. The mean direction is indicated by the black line running from the centre of the graph to the outer edge. The arcs extending to either side represent the 95% confidence limits of the mean direction.

7.2.10.2 ***Migration altitude***

The patterns of flight altitude displayed by migrating Marsh Harriers follow the same descending trend as most other raptors with a wide range of altitudes as the birds leave land, followed by descending altitudes as the birds cross the Baltic Sea (Figure 75). The angle of descend is quite steep, as illustrated by the lack of recorded altitudes above 300 m at the Danish coast and above 100 m at Kriegers Flak. The high mean altitude at 100 km distance from departing coast in headwinds is due to single observations of birds on arrival to the Swedish coast during spring 2011 (Figure 76). During head winds the harriers are obviously able to increase altitude as they approach the coast.

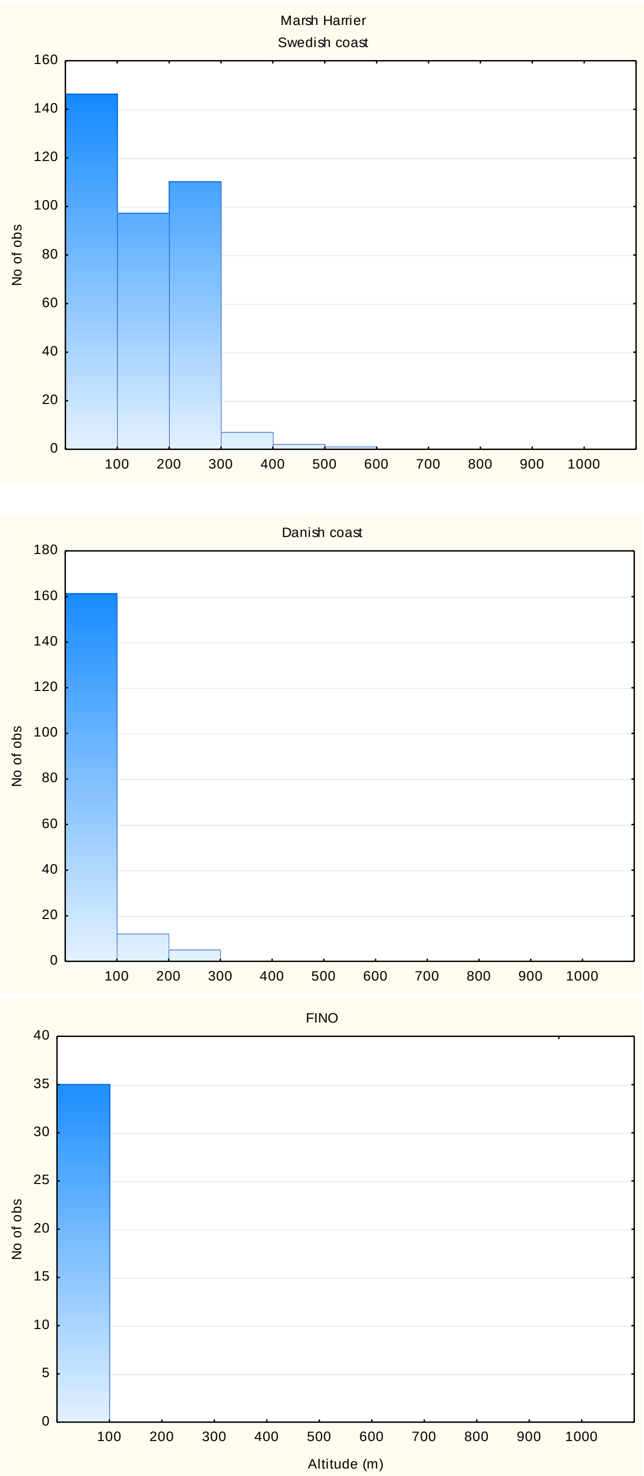


Figure 75. Frequency distribution of altitude measurements of Marsh Harrier by laser rangefinder at the Swedish south coast, at the Danish coast and at FINO 2 during autumn 2013.

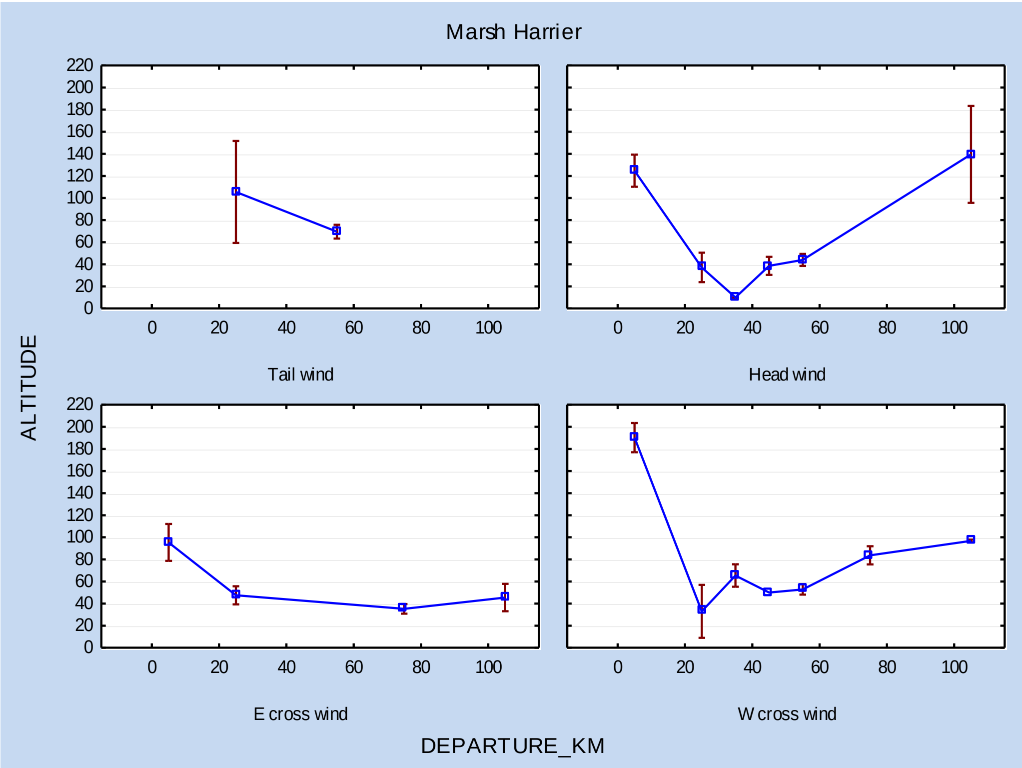


Figure 76. Changes in sampled altitude of Marsh Harrier by laser rangefinder during 2013 in relation to distance from the departure coast (north Germany in spring and south Sweden in autumn). Mean and confidence interval are given for different distances from departing coast and wind direction.

The GAMM flight model for Marsh Harrier in autumn shows that the birds fly higher in tail winds (northerly winds) and descend in altitude after leaving the coast (Figure 77). The birds also fly higher with increasing clearness. The predictive accuracy of the GAMM was reasonably high, with a good agreement between observed and predicted altitudes, a Spearman's rank correlation of 0.48, when the model was evaluated on semi-independent data (Table 20, Figure 78). The adjusted R^2 indicated also a reasonable fit (Table 20). The model successfully accounted for the strong temporal and spatial autocorrelation in the track data by using the correlation structure and random term (serial and spatial autocorrelograms and model diagnostics are shown in Appendix A). According to the predictions the birds fly on average at (during tail and cross winds) or below (in head winds) rotor height of the 10 MW turbines at Kriegers Flak during the different weather conditions (Figure 79). Graphs of the predictions including model standard errors are shown in the Appendix A.

Table 20. Significance and F-values for the fixed parametric (wind directions) and smooth terms included in the GAMMs for the Marsh Harrier. Adjusted R-square indicates the variance explained by the model and the Spearman's correlation coefficient the agreement between predicted and evaluated altitudes (by a split sample evaluation approach). Number of samples used in the analysis is shown on the bottom row.

		F-value	p-value
Smooth	Distance to coast: Wind direction	5.38	<0.01
	Clearness	2.83	0.09
R-sq. (adj)		0.44	
Spearman's corr.		0.48	
N of tracks (samples)		56 (526)	

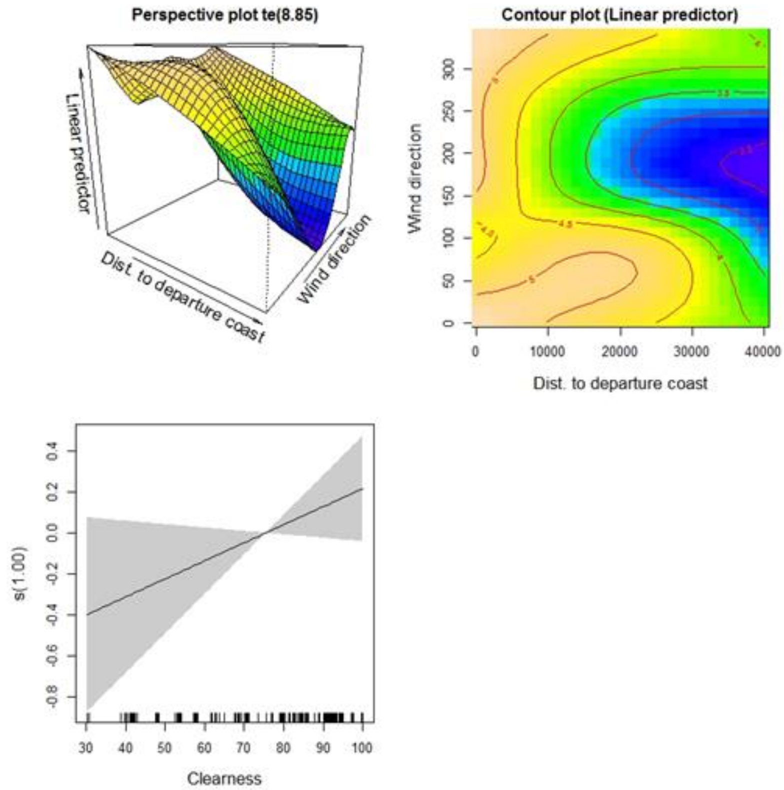


Figure 77. GAMM response curves for the Marsh Harrier. Both a perspective plot (3d) and a contour plot (2d) are shown for the interaction term (the tensor product smoother). The response is on the scale of the linear predictor. The degree of smoothing is indicated in the title of the interaction term (of the perspective plot) and in the title of the Y-axis for the 1d smooth functions. The shaded areas show the 95% Bayesian confidence intervals. Confidence intervals are not shown for the interaction term to improve interpretability.

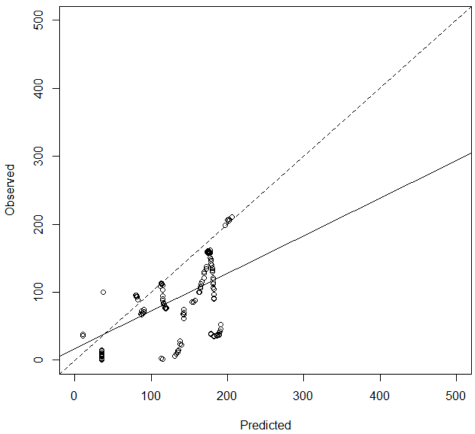


Figure 78. Split sample evaluation results: predicted average flight altitudes of Marsh Harriers against observed altitudes. The model was fitted on 70% of the tracks and was tested on 30%. The black line is a regression line based on a linear regression between observed and predicted altitudes. If the model would be perfectly calibrated all points would lie on the dashed line.

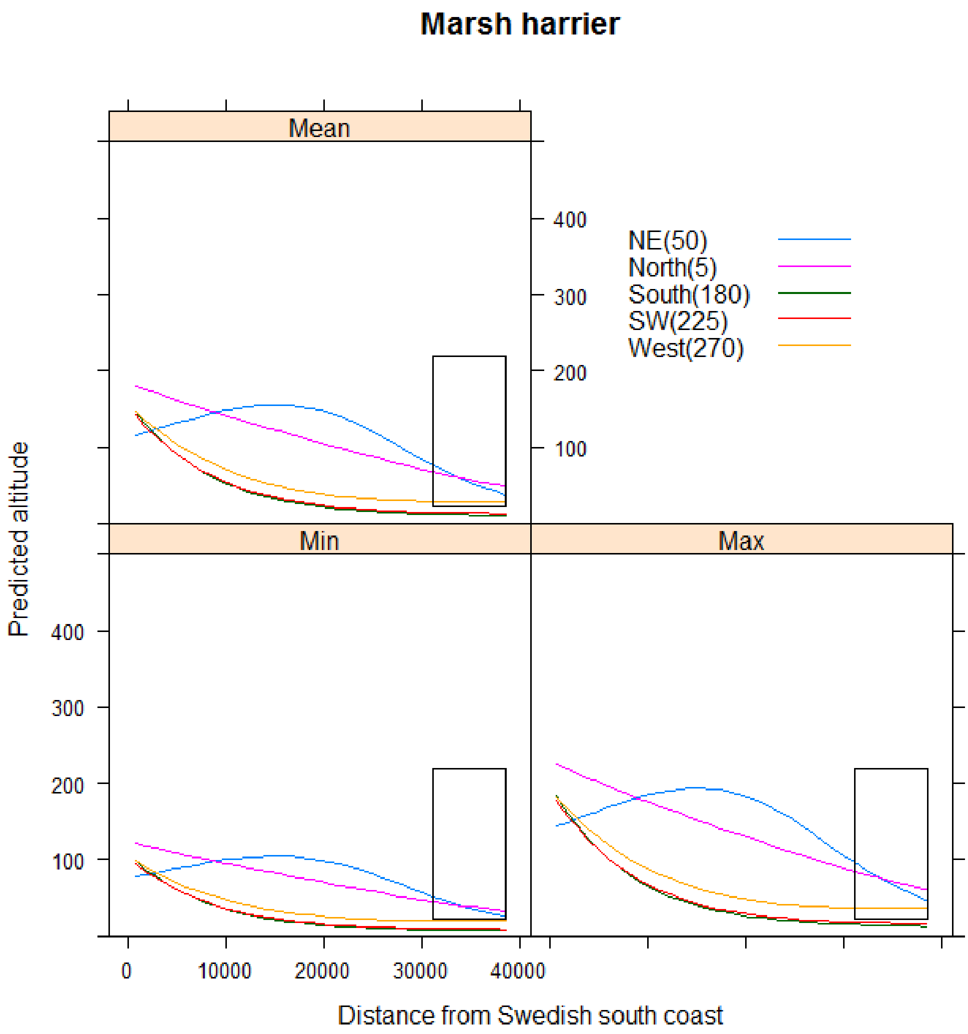


Figure 79. Average predicted altitude for Marsh Harriers in relation to distance from the coast of Sweden during different wind directions and wind speeds. All other predictor variables were set to mean values within the species specific data set. The lines are the predicted flight altitudes and the black rectangle indicates the rotor swept area by 10 MW turbines.

7.2.11 Kestrel

7.2.11.1 *Spatial distribution and migration direction*

According to Karlsson et al. (2004) 475 Kestrels leave Falsterbo on an average autumn season. Based on the rangefinder data collected during the baseline at Falsterbo 19% of the birds have directions indicating that they will cross the Arkona Basin, whereas the majority of directions are concentrated around SW in the direction of Stevns Klint in Denmark (Figure 80, Figure 81). Although some birds may leave Sweden before they reach Falsterbo the above proportion is most likely a reasonable approximation of the number of Sparrowhawks crossing, which using the mean figure from Falsterbo equals 90 birds. No figures on spring migration of raptors through the region are available, neither from this or other studies.

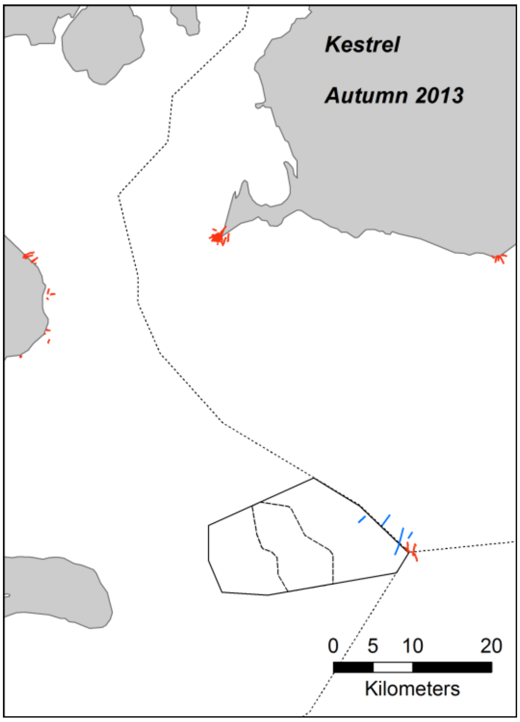


Figure 80. Migration tracks of Kestrel collected in the study area, spring and autumn 2013. Radar-based tracks are marked by blue lines, and rangefinder-based tracks by red lines.

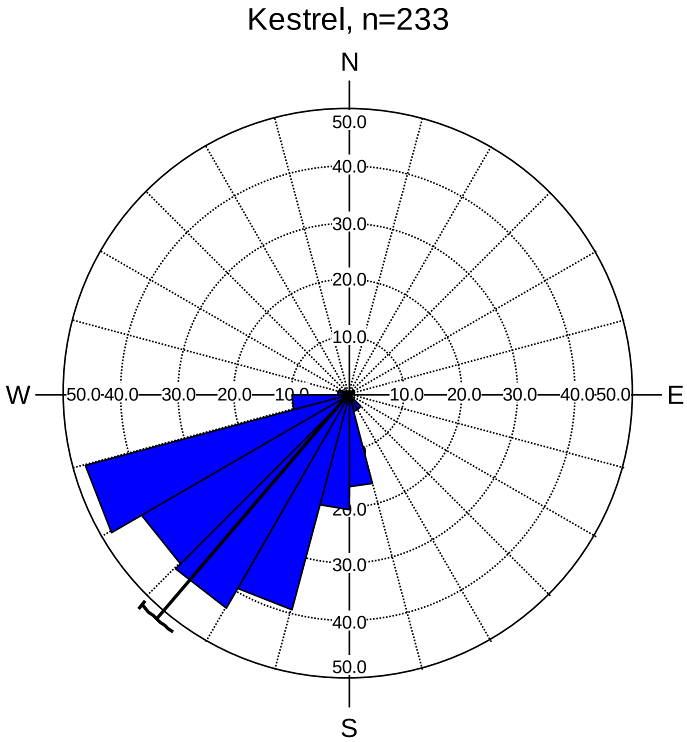


Figure 81. Sampled migration directions of Kestrel at Falsterbo, autumn 2013. Numbers on the Y-axes refer to sample size (number of recordings by laser rangefinder). Each wedge represents a sector of 15°. The mean direction is indicated by the black line running from the centre of the graph to the outer edge. The arcs extending to either side represent the 95% confidence limits of the mean direction.

7.2.11.2 ***Migration altitude***

The patterns of flight altitude displayed by migrating Kestrels are slightly different than those seen for other raptors (Figure 82, Figure 83). They do share the descending trend from the Swedish coast, yet the descend mainly seems to take place in tail winds when some birds fly above 100 m at the coast. As a result the angle of descend is significantly different between different wind directions (Table 21). In most situations Kestrels fly at altitudes below 100 m.

Table 21. Results of homogeneity of slope test testing whether tracks of Kestrel during different wind directions have different responses of altitude to distance to land. Only the results for the interaction between wind direction and distance to land are shown for the DHI rangefinder data collected from the Swedish coast autumn 2013.

Value	F	Df	p
4844	1.17	3	ns

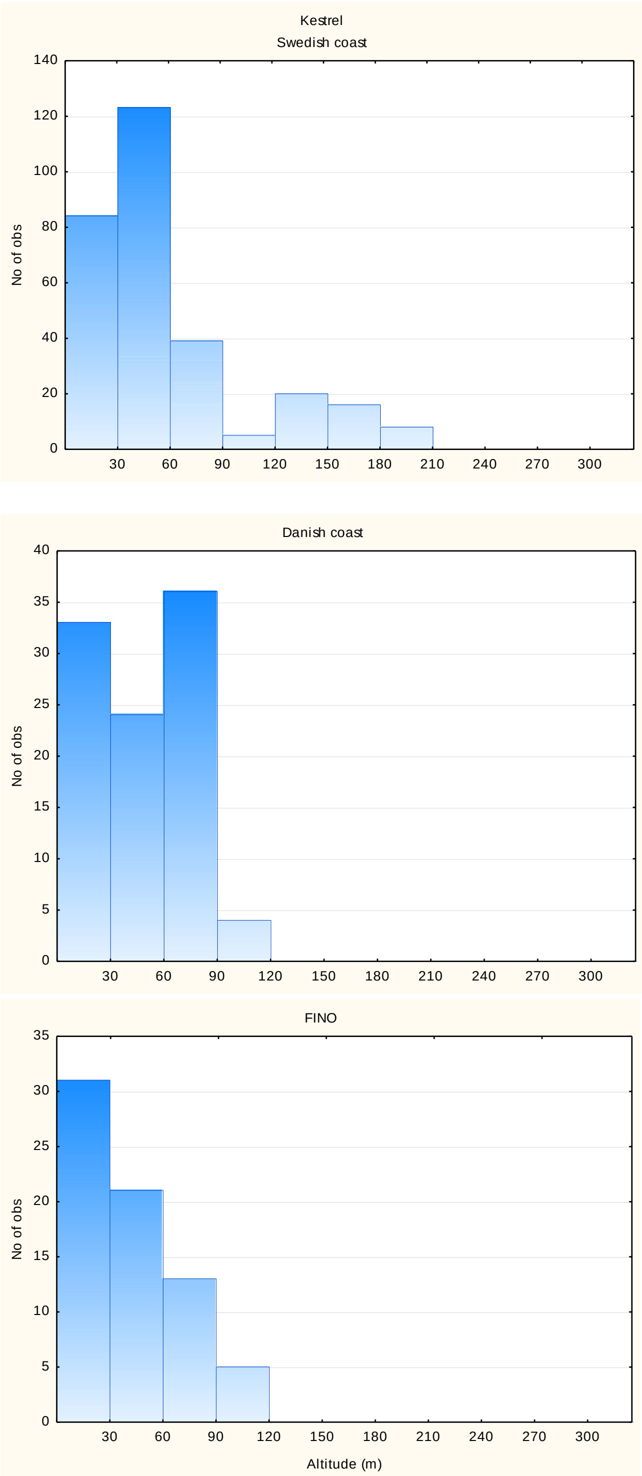


Figure 82. Frequency distribution of altitude measurements of Kestrel by laser rangefinder at the Swedish south coast, at the Danish coast and at FINO 2 during autumn 2013.

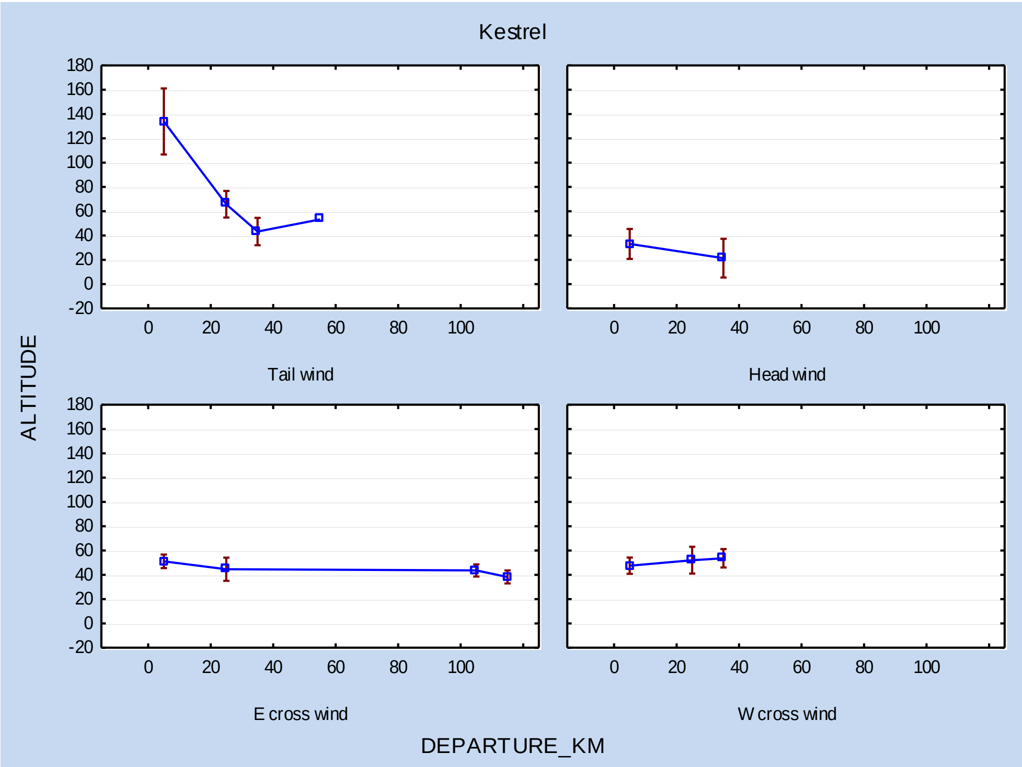


Figure 83. Changes in sampled altitude of Kestrel by laser rangefinder during 2013 in relation to distance from the departure coast (north Germany in spring and south Sweden in autumn). Mean and confidence interval are given for different distances from departing coast and wind direction.

7.2.12 **Other Falcons**

7.2.12.1 ***Spatial distribution and migration direction***

An insufficient sample of Hobby *Falco subbuteo* and Peregrine Falcon *Falco peregrinus* was obtained to allow for statistical analysis. Judged from the recorded migration directions at Falsterbo Hobbies may cross the Arkona Basin more often than Peregrine Falcons (Figure 84, Figure 85, Figure 86).

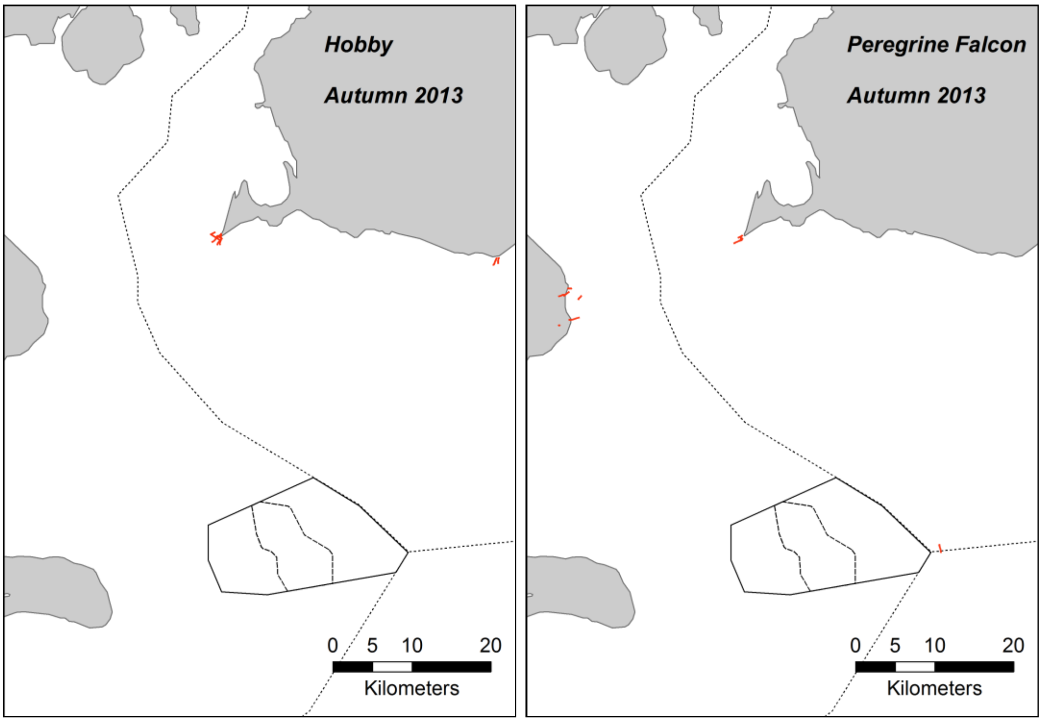


Figure 84. Migration tracks of Hobby and Kestrel collected in the study area, spring and autumn 2013. Radar-based tracks are marked by blue lines, and rangefinder-based tracks by red lines.

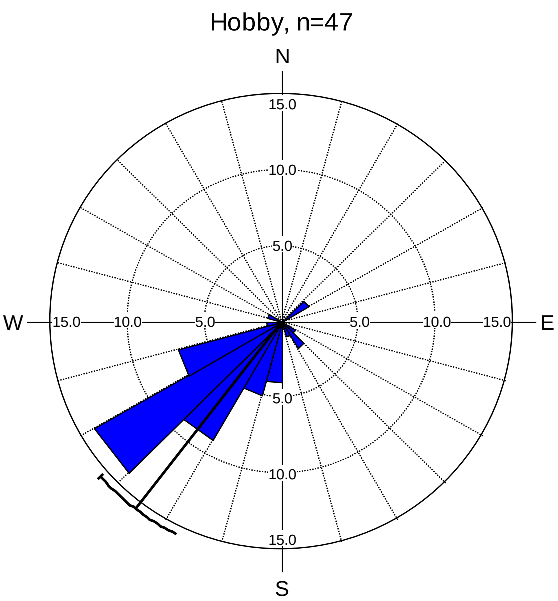


Figure 85. Sampled migration directions of Hobby at Falsterbo, autumn 2013. Numbers on the Y-axes refer to sample size (number of recordings by laser rangefinder). Each wedge represents a sector of 15°. The mean direction is indicated by the black line running from the centre of the graph to the outer edge. The arcs extending to either side represent the 95% confidence limits of the mean direction.

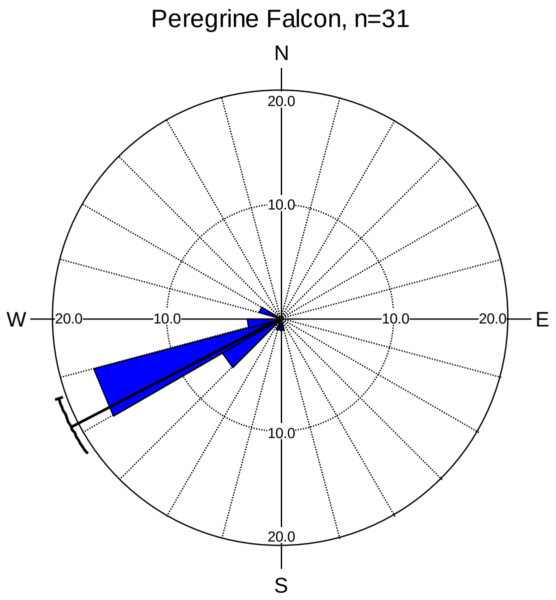


Figure 86. Sampled migration directions of Peregrine Falcon at Falsterbo, autumn 2013. Numbers on the Y-axes refer to sample size (number of recordings by laser rangefinder). Each wedge represents a sector of 15°. The mean direction is indicated by the black line running from the centre of the graph to the outer edge. The arcs extending to either side represent the 95% confidence limits of the mean direction.

7.2.13 **Common Crane**

7.2.13.1 ***Spatial distribution and migration direction***

The total Swedish and Norwegian populations (including juveniles) was estimated at 84,000 individuals (Wetlands International 2012), and they cross the Arkona Basin over a broad front both during spring and autumn (Figure 87). The population in northern Europe has shown an increasing trend at least over the past 27 years; 0.84% per year from 1988-2012 and 2.43% per year from 2003-2012 (Wetlands International 2012). Even though the tracks obtained by satellite GPS telemetry in 2013 indicate that most birds may cross centrally, telemetry data from the Swedish University of Agricultural Sciences from 2011-2012 show otherwise and stress that the birds indeed may cross anywhere between Bornholm and the coast of Zealand, Møn and Falster (Figure 88). During autumn most birds stage on wetlands in Rügen, Germany, while during spring most birds stage 50 km further west in the Darss area. Whether these changes in key staging areas give rise to different mean migration routes across the basin during spring and autumn is unknown. However, judged from a review of the historic locations of large observations of Common Crane along the Swedish south coast (2000-2012) the spatial variation in exit sites is mainly controlled by the wind direction. The vast majority of directions from Falsterbo in autumn 2013 were concentrated around S in the direction of Rügen (Figure 89). During spring 2013, the mean direction of migrating Common Crane was 13°.

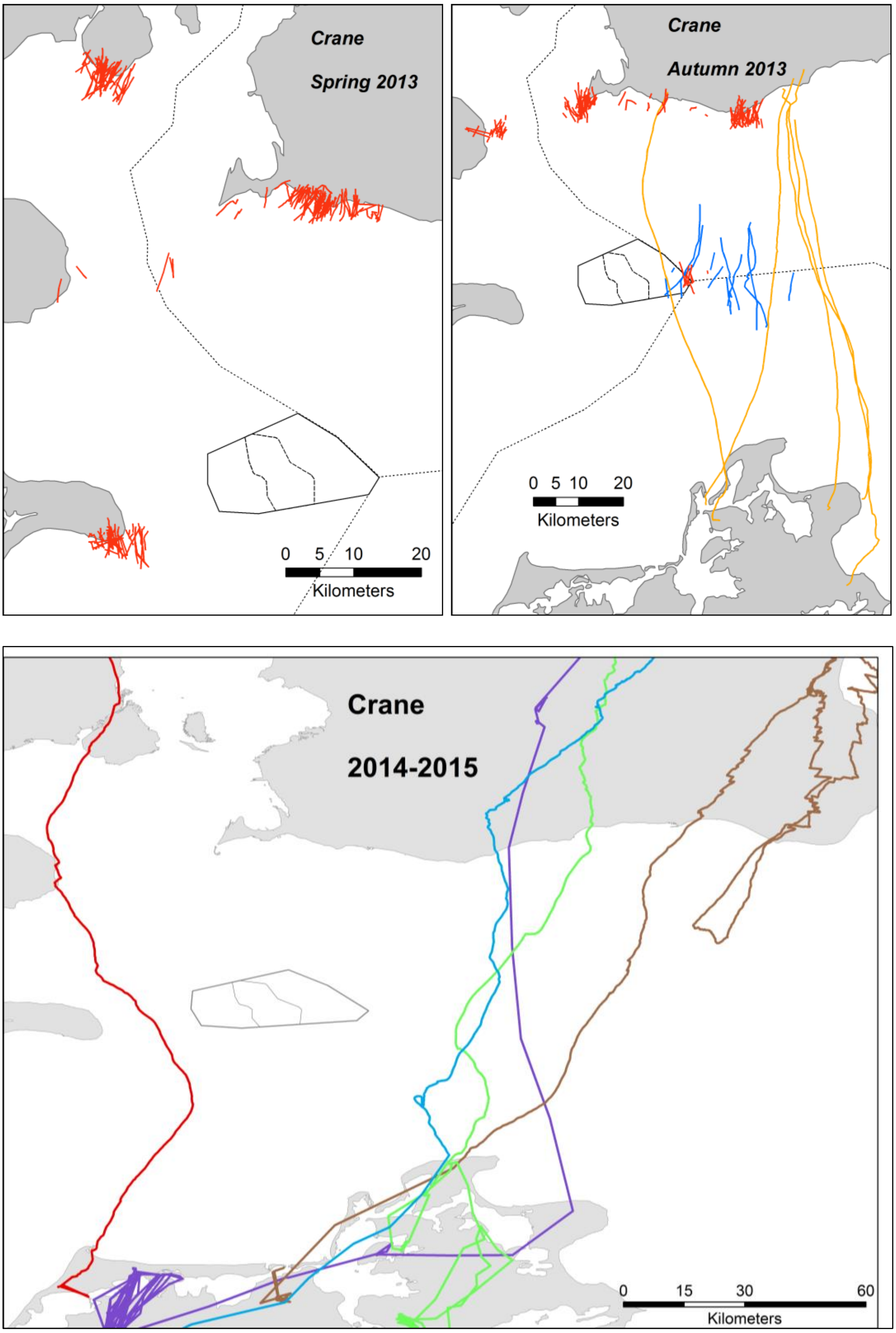


Figure 87. Migration tracks of Common Crane collected in the study area. Upper panel: spring and autumn 2013 - GPS-telemetry tagged birds are indicated by orange lines, radar-based tracks are marked by blue lines, and rangefinder-based tracks by red lines. Lower panel: GPS-telemetry tagged birds 2014-2015. Tracks recorded by radar and rangefinder during the behavioural investigations at the Baltic 2 offshore wind farm spring 2015 are shown in chapter 7.2.13.3.

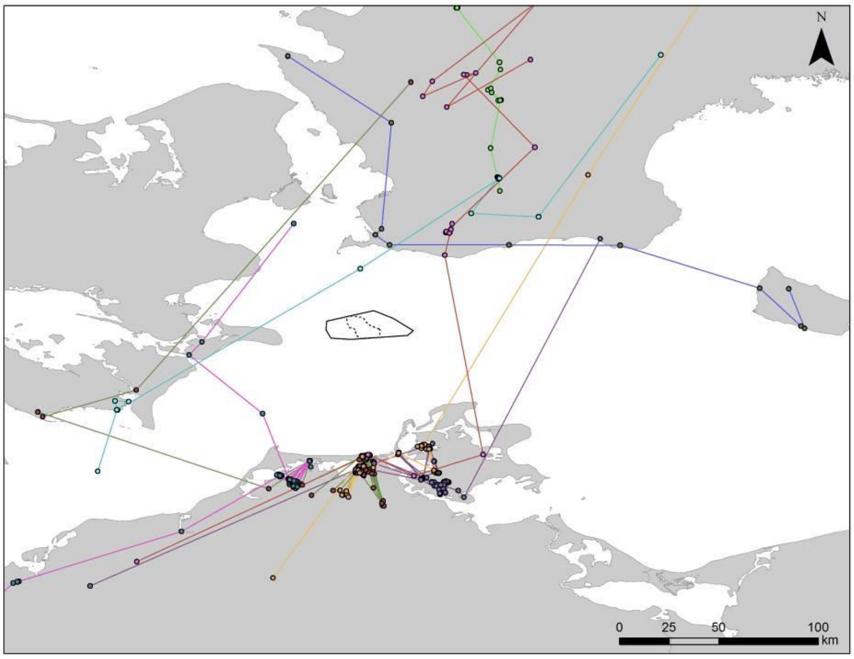


Figure 88. Migration tracks of ten GPS-tagged Common Crane collected in the study region during 2011-2012 (Courtesy Swedish University of Agricultural Sciences). Tracks over the sea are lines combining adjoining GPS positions logged on land, and do not show actual flight paths.

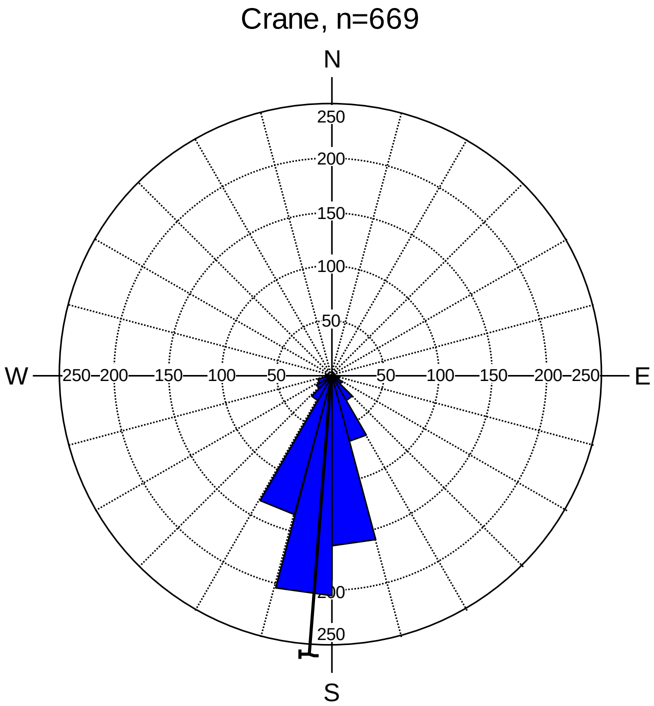


Figure 89. Sampled migration directions of Common Crane at Falsterbo, autumn 2013. Numbers on the Y-axes refer to sample size (number of recordings by laser rangefinder). Each wedge represents a sector of 15°. The mean direction is indicated by the black line running from the centre of the graph to the outer edge. The arcs extending to either side represent the 95% confidence limits of the mean direction.

7.2.13.2 *Migration altitude*

The patterns of flight altitude displayed by migrating Common Crane are very similar to those observed for the raptors, yet a higher proportion of the Common Crane may cross Kriegers Flak at altitudes above 200 m. The general descend in flight altitude from the Swedish coast in autumn is nonetheless very clear (Figure 90,). During spring, most Common Crane arrive to Denmark and Sweden at altitudes between 150 and 200 m (Figure 90). During spring, the profile seems to depend on wind direction, with birds descending during tail winds and ascending during head winds. Thus, the Common Crane can use thermals drifting offshore to gain altitude at distances of up to 5 km from the coast. The samples affected by thermals were therefore removed from the data set used for the altitude models.

During autumn steep descends are seen in both tail wind and head wind, the descend being slightly steeper in head winds. On average birds seem to cross the Arkona Basin at lower altitude during tail winds than head winds in autumn (Figure 90). The GPS-tagged birds demonstrate how some Cranes (2 of 11 crossings) during optimal conditions can cross the Kriegers Flak region at heights above 400 m altitude (Figure 91).

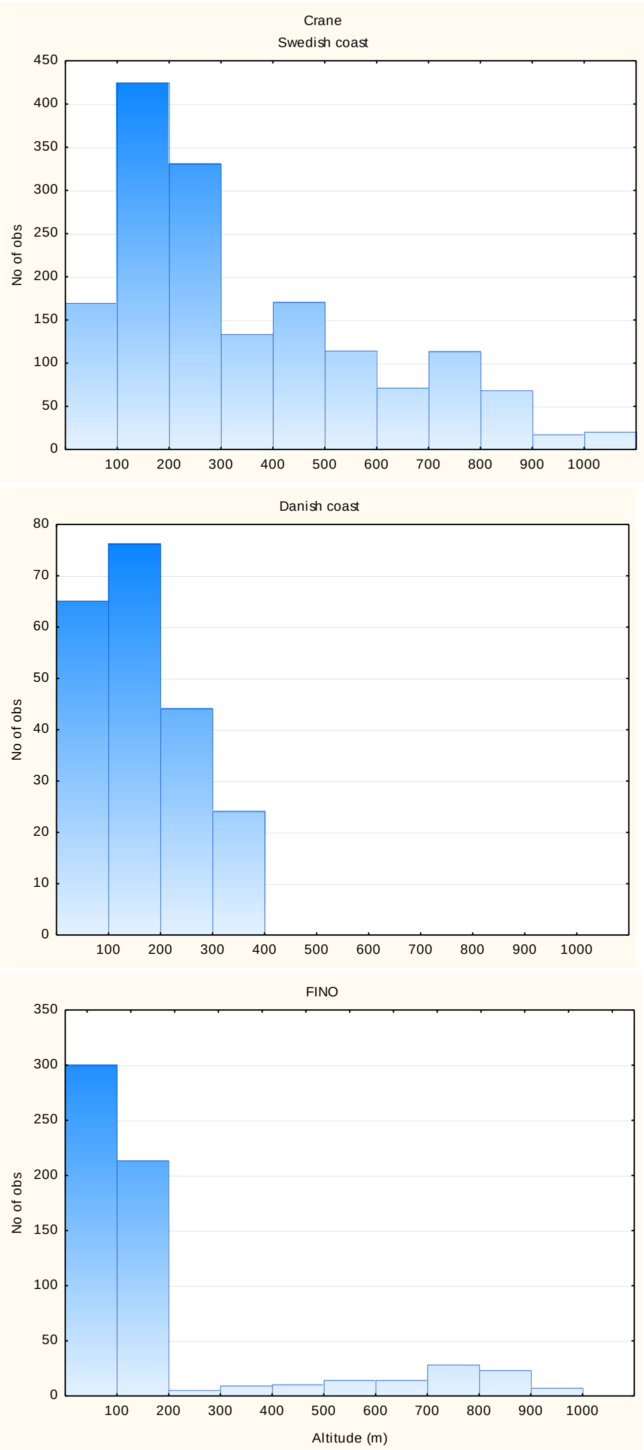
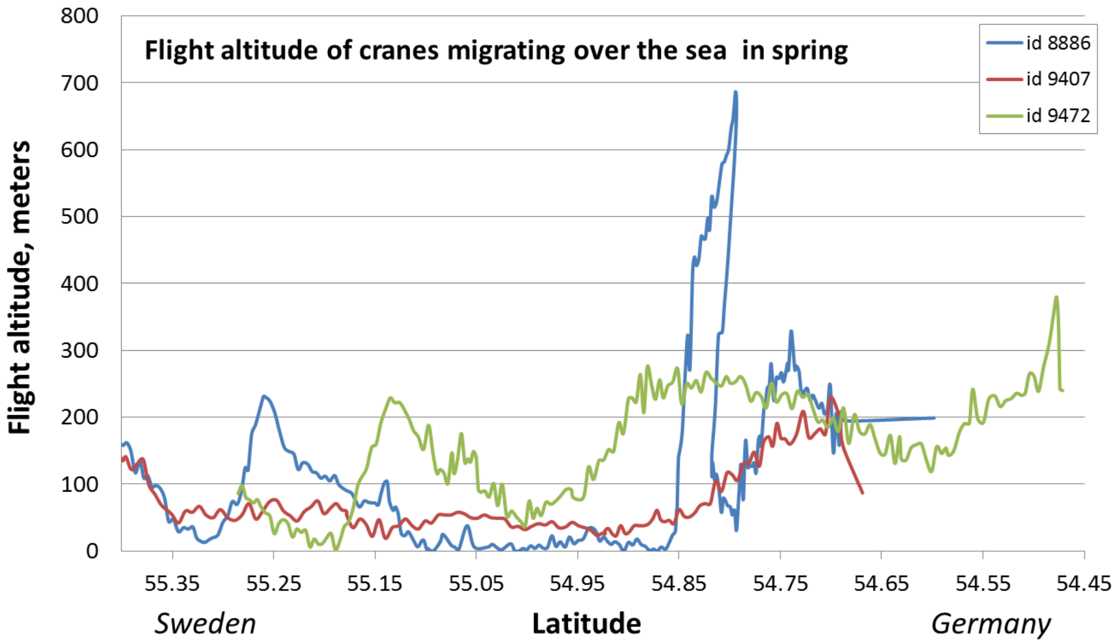


Figure 90. Frequency distribution of altitude measurements of Common Crane by laser rangefinder at the Swedish south coast, at the Danish coast and at FINO 2 during baseline, autumn 2013.



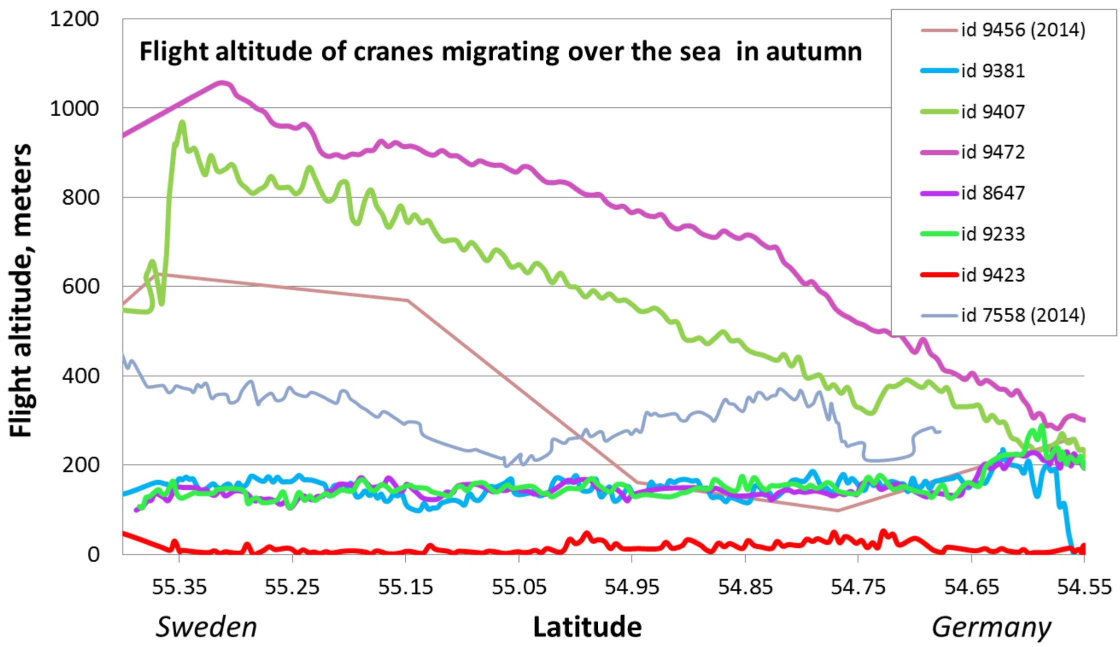


Figure 91. Heights measurements of 11 GPS-tagged Common Crane 2013-2015. Kriegers Flak is located at latitude 55.00° N.

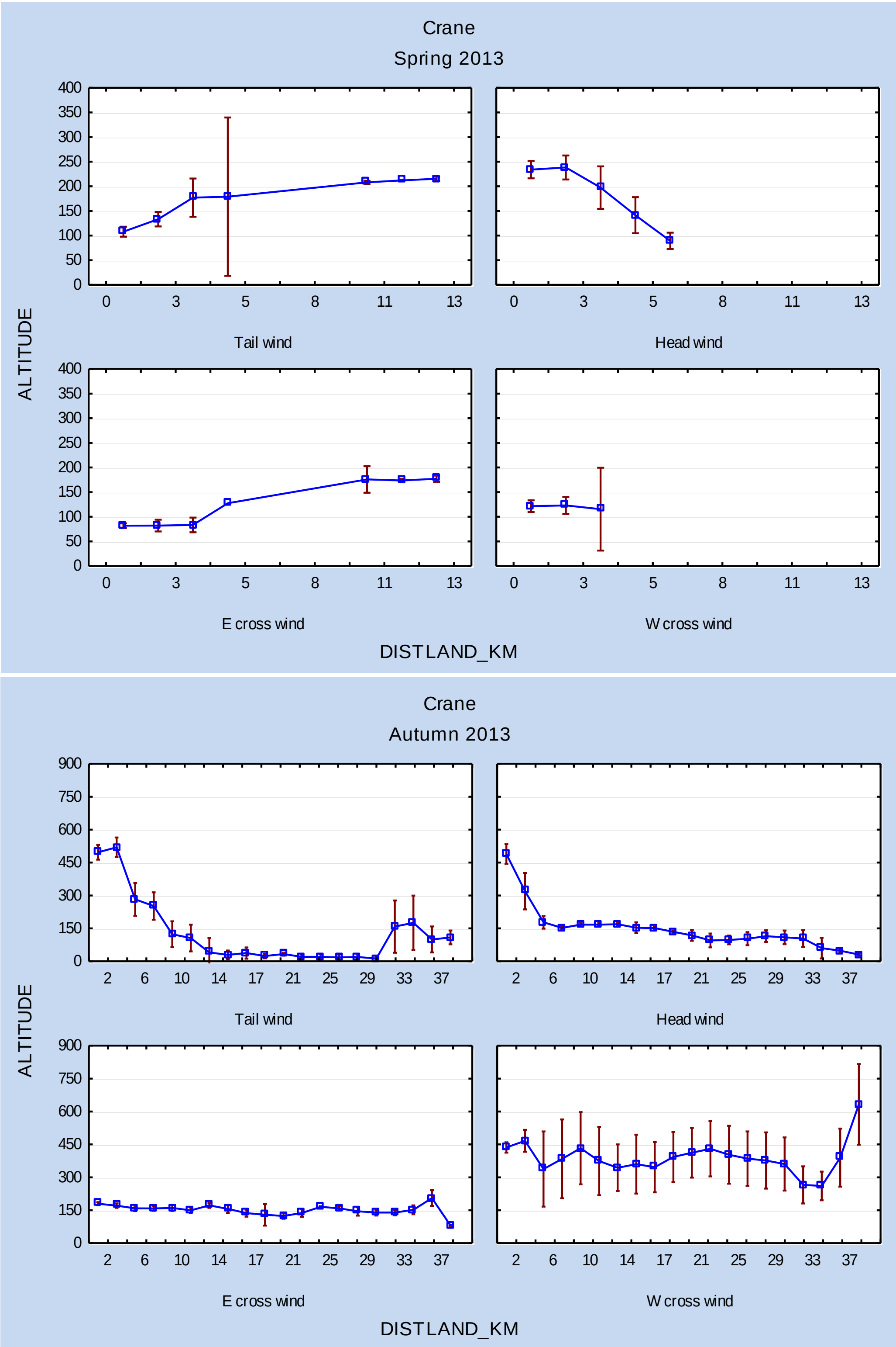


Figure 92. Changes in sampled altitude of Common Crane by laser rangefinder in relation to distance from coast during baseline in spring and autumn 2013. Mean and confidence interval are given for different distances from departing coast and wind direction.

7.2.13.3 *Investigation of behavioural responses of Common Crane at Baltic 2 Offshore Wind Farm*

During the investigation of behavioural responses of Common Crane to the Baltic 2 Offshore Wind farm a total of 74 tracks were recorded by observers using radars and rangefinders during the period 19 March to 20 April 2015 (Figure 93). Of this sample, 14 tracks were recorded as the birds were approaching the wind farm from the south, and hence could be used to infer macro avoidance, while 38 tracks were recorded in the wind farm for which changes in behaviour could be determined as hence meso avoidance behaviour determined. In four cases when relatively short tracks were recorded in between turbine rows the meso avoidance behaviour could not be recorded. Examples of meso and macro avoidance behaviour are visualised in Figure 94 and Figure 95.

The recorded flight heights in the Baltic 2 offshore wind farm during the behavioural investigation in 2015 closely resembled the baseline recordings from FINO 2 in 2013 (Figure 96), and were also in agreement with the model predictions based on the baseline recordings (see chapter 7.2.13.4). However, a slightly larger proportion of tracks were recorded in the wind farm in the interval between 150 m and 200 m in 2015 as compared to the baseline recordings. As the birds approached the Baltic 2 wind farm at some distance there was a tendency for a slight reduction in flight height, while closer to the wind farm the birds clearly increased height (Figure 97). The increase in flight altitude was also evident when evaluated as a function of distance to each turbine (Figure 98). Although the mean flight height close to the turbines were above the tip of the rotor (140 m), the confidence interval shows overlap with the height of the rotor swept zone.

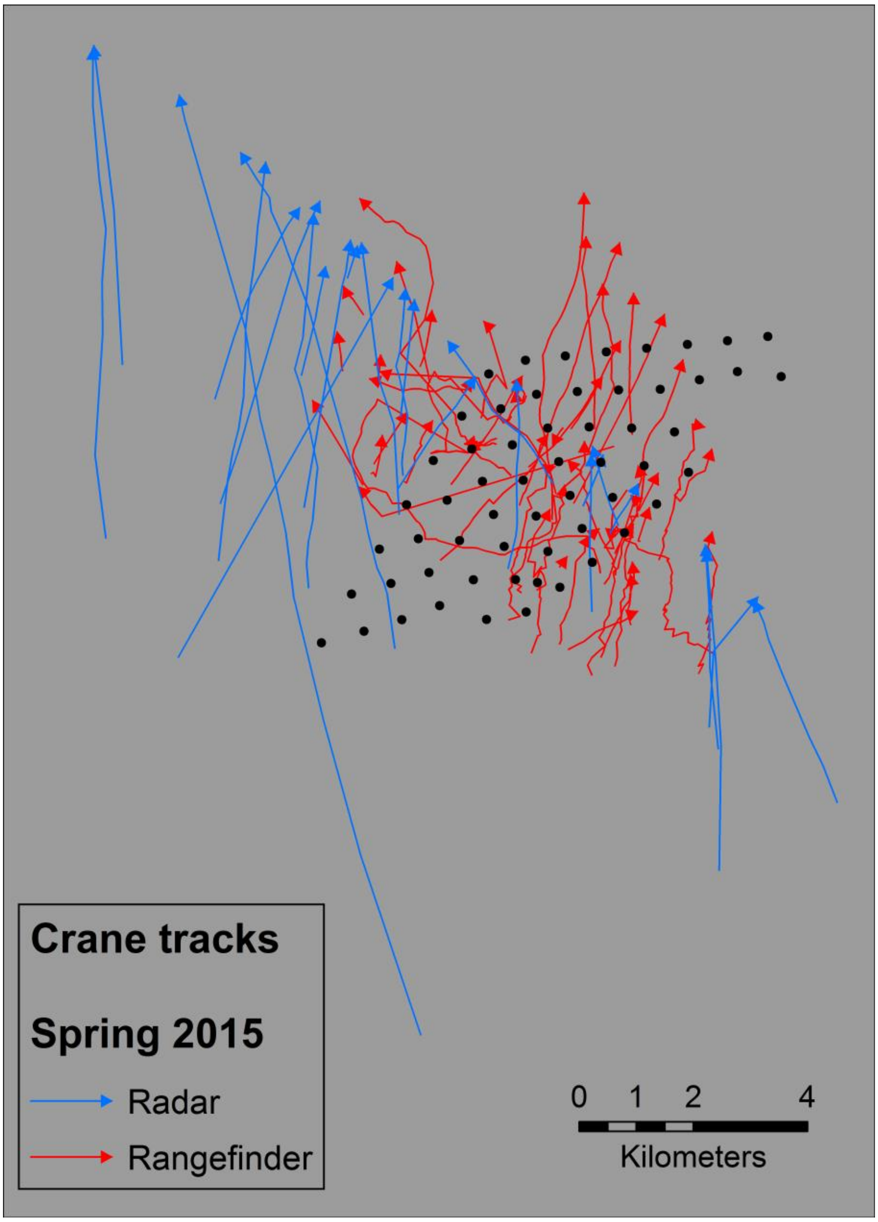


Figure 93. All tracks recorded by radar and rangefinder at the Baltic 2 offshore wind farm spring 2015. Note that turbines in the southernmost two rows were not installed during the investigation and have not been included in the map.

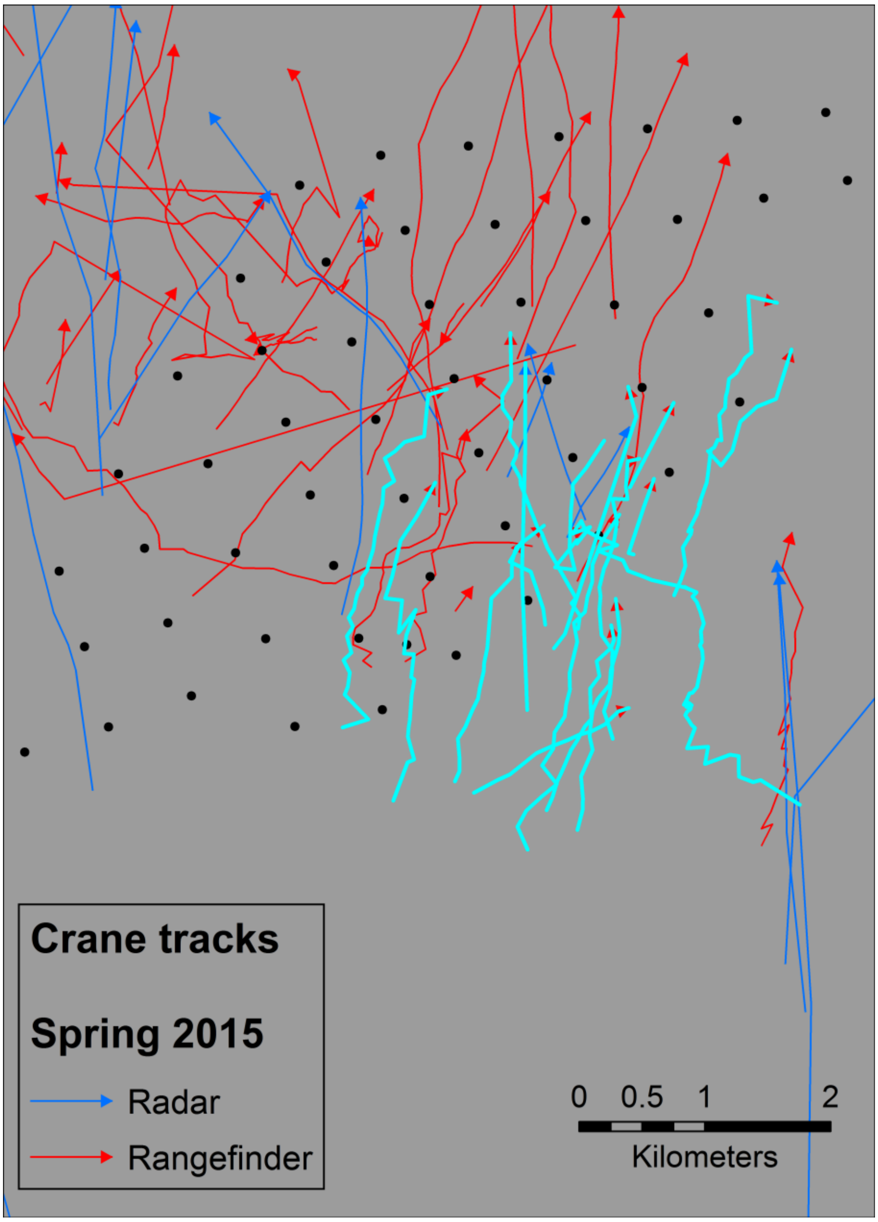


Figure 94. Tracks used for assessment of macro avoidance behaviour at the Baltic 2 offshore wind farm spring 2015 (marked by light blue lines). Note that turbines in the southernmost two rows were not installed during the investigation and have not been included in the map.

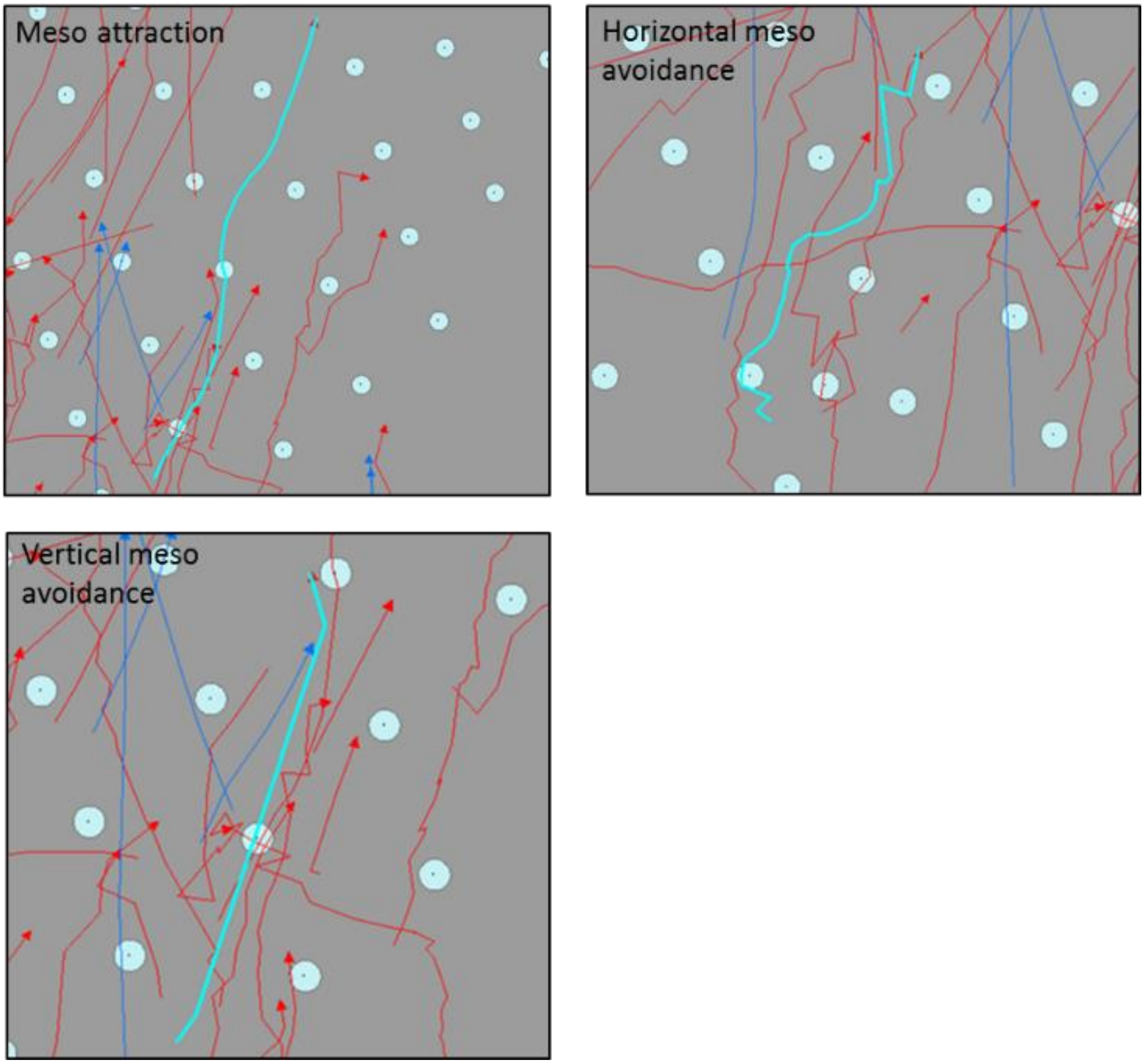


Figure 95. Examples of tracks (light blue line) showing meso attraction and avoidance behaviour at the Baltic 2 offshore wind farm spring 2015. Red lines are radar tracks and blue lines rangefinder-based tracks.

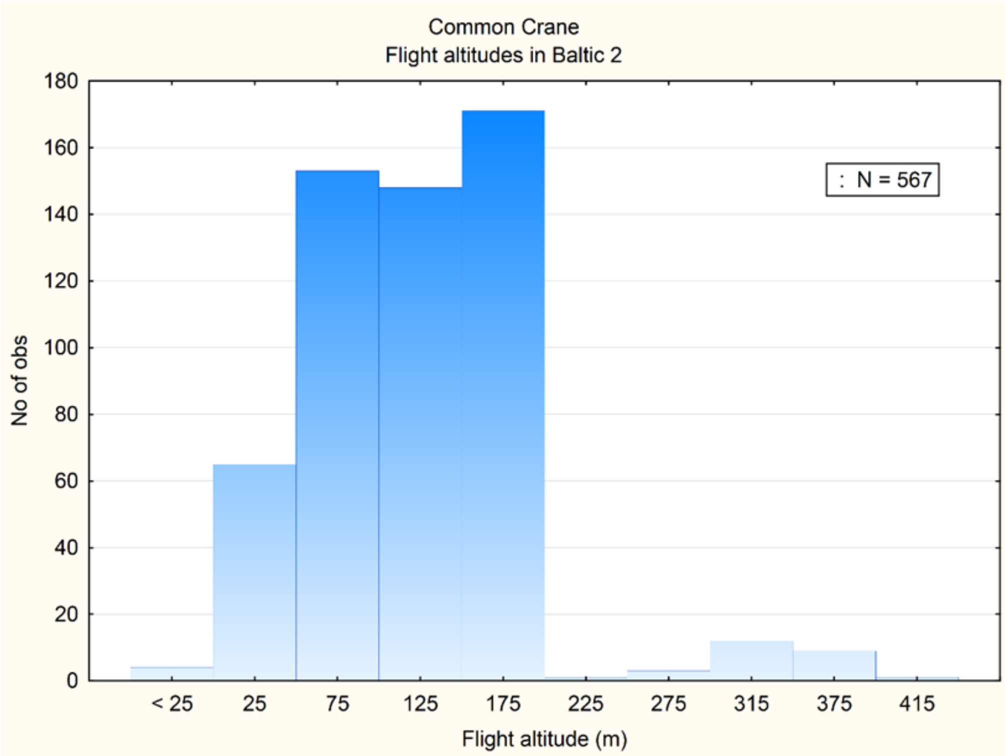


Figure 96. Frequency distribution of altitude measurements of Common Crane by laser rangefinder in the Baltic 2 offshore wind farm spring 2015.

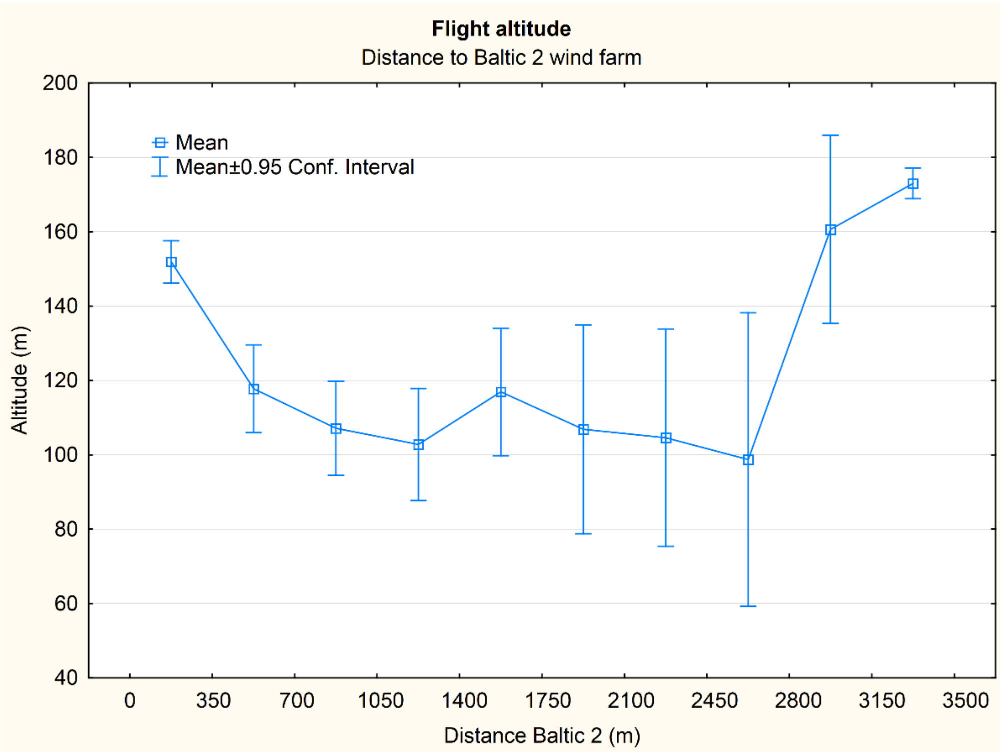


Figure 97. Mean and confidence interval of measured flight heights as a function of distance to Baltic 2 offshore wind farm spring 2015.

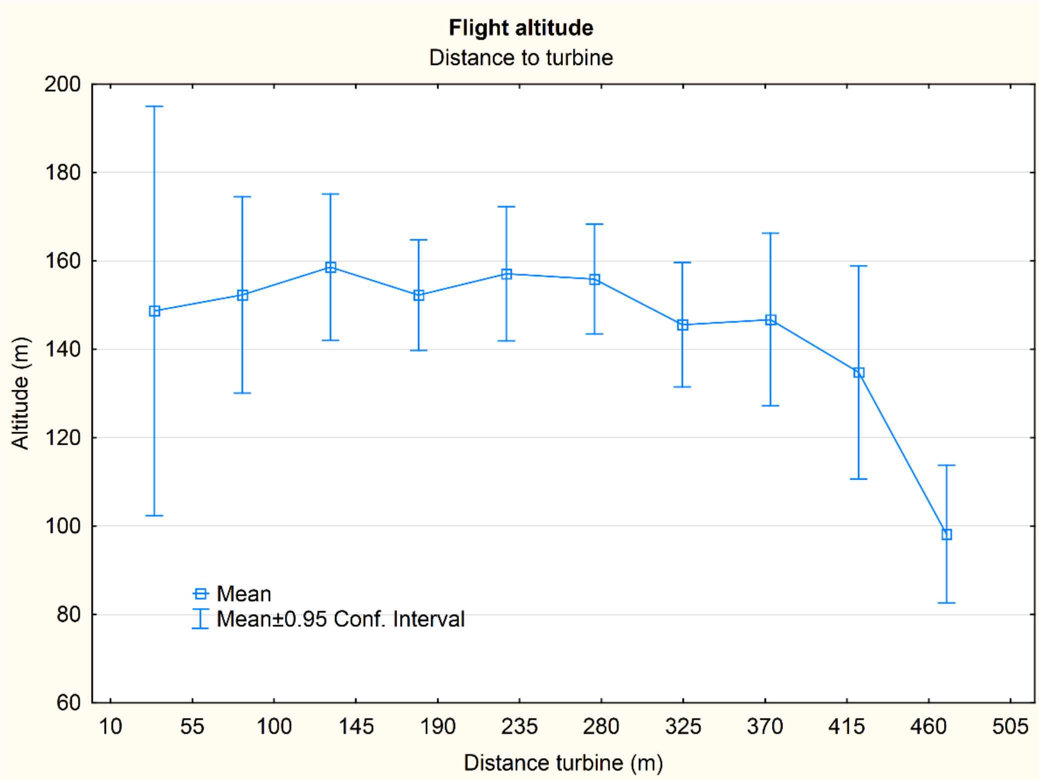


Figure 98. Mean and confidence interval of measured flight heights as a function of distance to individual turbines in the Baltic 2 offshore wind farm.

Figure 99. Examples of horizontal (left panel) and vertical (right panel) meso avoidance by Common Crane recorded in the Baltic 2 offshore wind farm spring 2015.

7.2.13.4 ***Flight models (to be updated in final version)***

The GAMM flight model for the Common Crane indicates that the birds descend in altitude after leaving the coast, and fly higher in clearer weather and decreasing humidity (Figure 100). The predictive accuracy of the GAMM was high, with a good agreement between observed and predicted altitudes, a Spearman's rank correlation of 0.40 (Tabel 22, Figure 101). The adjusted R^2 indicated that there is a lot of variance in the data that could not be explained by the model (Tabel 22). However, the model fit can otherwise be regarded as good as we were able to account for the strong temporal and spatial autocorrelation in the track data by using the correlation structure and random term (serial and spatial autocorrelograms and model diagnostics are shown in Appendix A). It should be pointed out that the model was best at predicting intermediate flight altitudes, whereas predictions at very high or low altitudes were less precise.

We further used the models for predicting the average seasonal flight altitude during average, poor and good visibility and during tail, head and cross winds. According to the predictions the birds fly on average at rotor height of the 10 MW turbines during all weather conditions and during both seasons, but fly slightly lower in spring. According to the predictions the birds fly slightly above the 3 MW turbines during good visibility conditions in autumn and also during average visibility conditions in autumn with tail or westerly cross winds. During situations with poor visibility and during average visibility with head and easterly cross wind combinations the birds will fly at the height of the 3 MW rotor (Figure 102, plots including model standard errors are shown in the Appendix A). In average the birds fly slightly higher in tail wind and westerly cross winds in comparison to head winds and easterly crosswinds.

Table 22. Significance and F-values for the smooth terms included in the GAMMs for the Common Crane. Adjusted R^2 indicates the variance explained by the model and the Spearman's correlation coefficient the agreement between predicted and evaluated altitudes (by a split sample evaluation approach). Number of samples used in the analysis is shown on the bottom row.

		F-value	p-value
Smooth	Distance to departure coast	43.235	<0.01
	Wind direction, Spring	4.823	<0.01
	Wind direction, Autumn	2.026	0.06
	Clearness	2.349	0.125
	Humidity	14.526	<0.01
R-sq. (adj)		0.352	
Spearman's corr.		0.40	
N of tracks (samples)		382 (4857)	

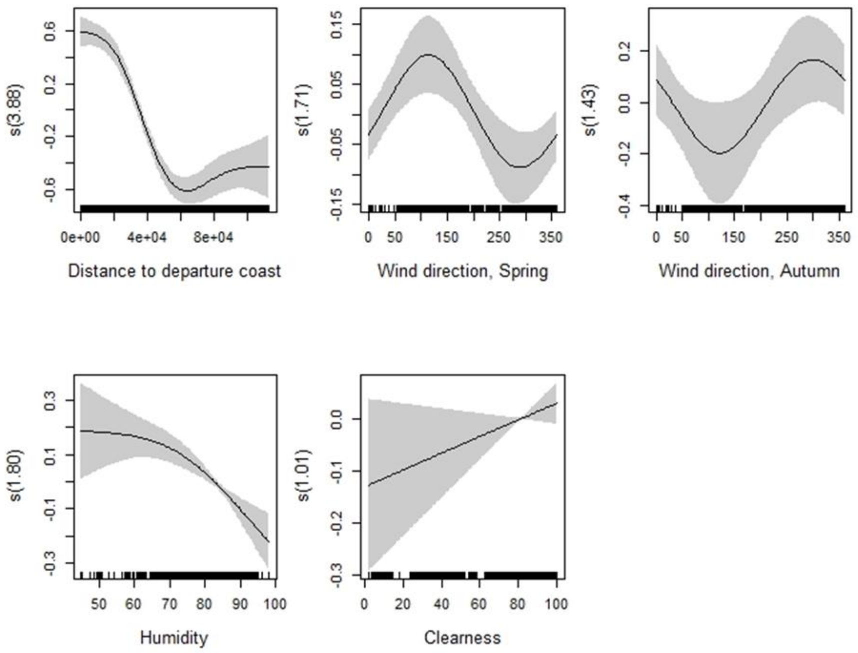


Figure 100. GAMM response curves for the Common Crane based on data from both spring and autumn. The values of the environmental predictors are shown on the X-axis and the response on the Y-axis is on the scale of the linear predictor. The degree of smoothing is indicated in the title of the Y-axis. The shaded areas and the dotted lines show the 95% Bayesian confidence intervals.

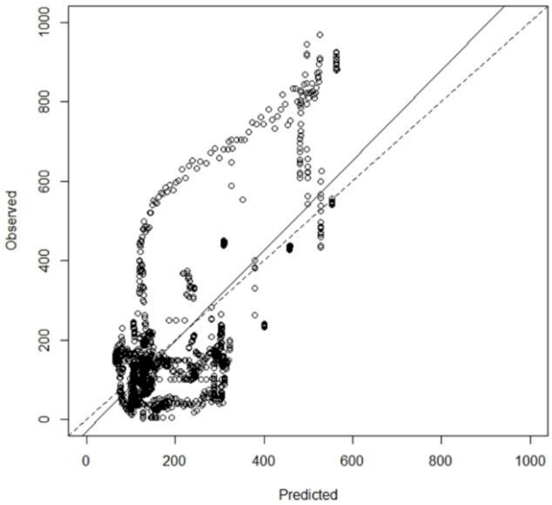
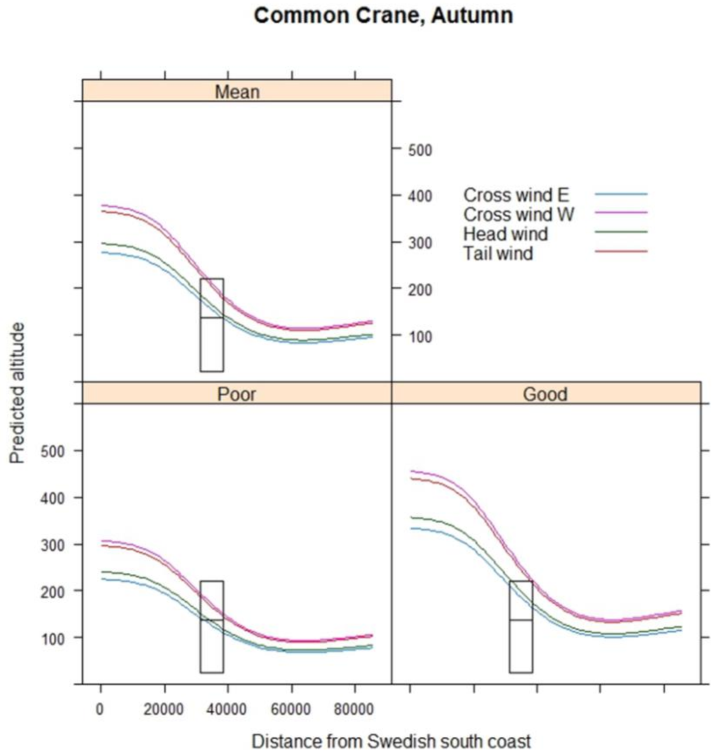


Figure 101. Split sample evaluation results: predicted average flight altitudes of Common Crane against observed altitudes. The model was fitted on 70% of the tracks and was tested on 30%. The black line is a regression line based on a linear regression between observed and predicted altitudes. If the model would be perfectly calibrated all points would lie on the dashed line.



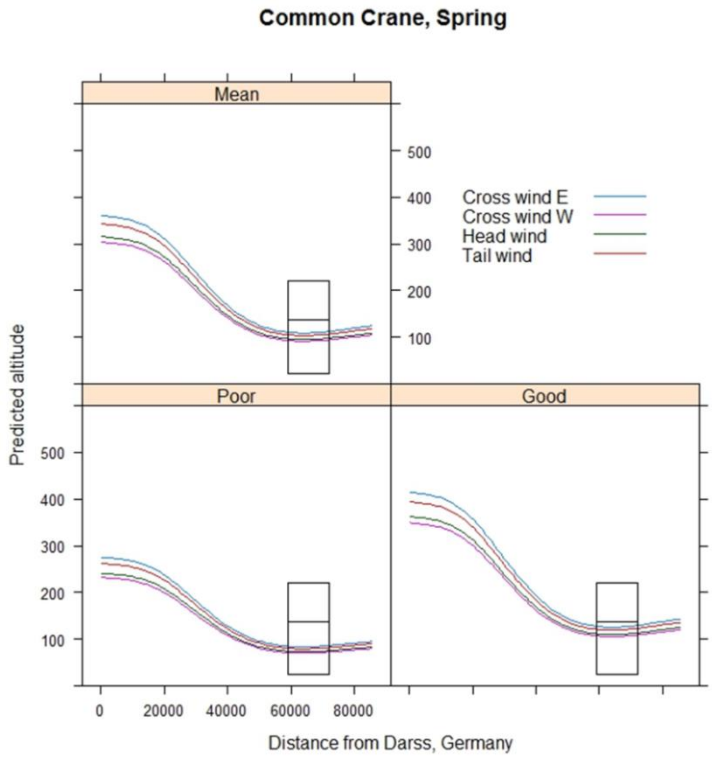


Figure 102. Average predicted altitude for Common Crane in relation to distance from the coast of Sweden during different visibility and wind directions for the spring and autumn seasons. All other predictor variables are set to mean values within the species specific data set. The lines are the predicted flight altitudes and the black rectangle indicates the rotor swept area by 10 MW turbines. The line dividing the rectangle indicates the height of a 3 MW turbine.

7.3 Bat migration at Kriegers Flak

The acoustic recordings of bats at Kriegers Flak is shown in Table 23.

Table 23. Acoustic recordings of bats at FINO 2.

Date/Species	Noctule/Party-colouredbat	Noctule bat	Serotine bat	Nathusius's Pip-istrelle Bat	SParty-coloued bat	Bat ssp.	Total
04-08-2013			2				2
19-08-2013					8		8
20-08-2013					7		7
25-08-2013					1		1
28-08-2013		6					6
29-08-2013		4		1			5
30-08-2013		2		1			3
04-09-2013		2		13			15
05-09-2013				4			4
11-09-2013				215			215
12-09-2013				9			9
13-09-2013	1	2		1			4
14-09-2013		2					2
15-09-2013						2	2
18-09-2013			1				1
20-09-2013				1			1
23-09-2013		1			1		2
Total	**1**	**19**	**3**	**245**	**17**	**2**	**287**

7.3.1 Nathusius's Pipistrelle Bat

This species was recorded in higher numbers on Kriegers Flak than other species of bats. Particularly on the 11 September when recordings of 215 animals were made. The species belongs to the genus Pipistrellus, and is reasonable common in many parts of Denmark (Figure 103). During migration, spring and autumn, it can occur anywhere in the country, including on oil rigs in the North Sea (Baagøe 2007). Nauthusius's Pipistrelle bats are listed on the EC Habitats Directive Annex IV, but are not listed as vulnerable on the Danish Red List.

As the Nauthusius's Pipistrelle bat is that of the Nordic bats with the largest distance between summer and winter quarters, it can be considered as a long-distance migrant. The main migration direction is southwest. Among 60,000 tagged Nauthusius's Pipistrelle bats in Europe the longest recorded migration distance was 1,905 km (Dietz et al. 2007). The average distance a Nauthusius's Pipistrelle bat travels on a night is 29-48 km (Dietz et al. 2007).

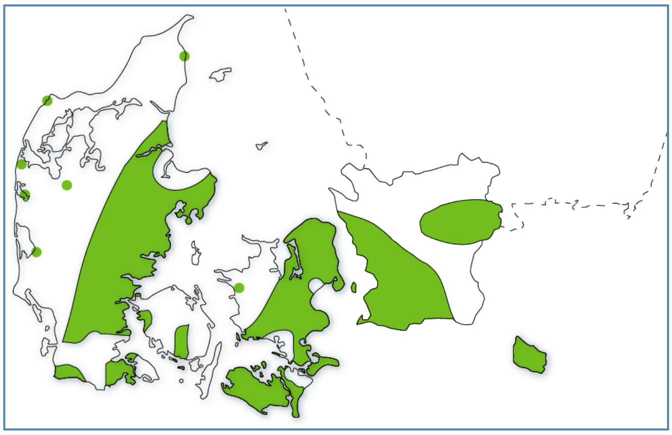


Figure 103. Distribution of Nathusius's Pipistrelle Bat. For Denmark the distribution is based on Baagøe & Jensen (2007), and for Skåne on Gerell (2011).

7.3.2 Noctule Bat

The noctule bat is the largest bat species in Denmark, and a species that often can be seen hunting before dark. It is reasonably common in large parts of Denmark (Figure 104). During migration, spring and autumn, it can occur anywhere in the country, and was recorded regularly on Kriegers Flak.

Noctule bats are known to travel a great distance between summer and winter quarters with a mean direction towards southwest. Maximum migration distance recorded is 1,546 km, while the average distance is usually less than 1,000 km (Dietz et al. 2007).

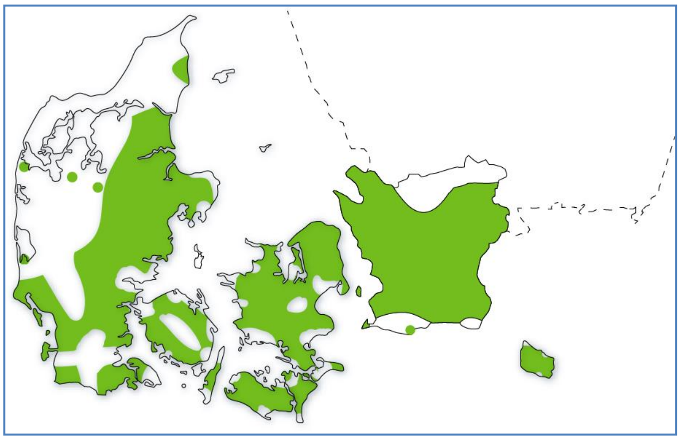


Figure 104. Distribution of Noctule Bat. For Denmark the distribution is based on Baagøe & Jensen (2007), and for Skåne on Gerell (2011).

7.3.3 Parti-coloured Bat

The parti-coloured bat has its main distribution in eastern Denmark. The population in northern Europe is the densest in the world (Baagøe 2007).

The Danish and Scandinavian populations of the species are mostly sedentary (Dietz et al. 2007), but it is however known to roam around a bit by carrying out regular features (Baagøe 2007). Especially Eastern European populations are known to disperse, the longest recorded distance is 1.787 km from Rybachy in Russia to France (Dietz et al. 2007).

7.3.4 Serotine Bat

The Serotine Bat is one of Denmark's most widespread bats. The species has been well integrated into man-made environments, and has spread significantly over the past 150 years (Baagøe 2007).

This bat species is predominantly sedentary, and it rarely moves over longer distances as the winter quarters are usually located within a 50 km radius. However, examples exist of Serotine Bats moving distances up to 330 kilometers.

8 Assessment of effects on birds in the construction period

In the following the expected impacts of the construction activities on birds is assessed. Although impacts on bird migration cannot be ruled out during the construction phase the assessment focuses on impacts on non-breeding waterbirds. As the construction of gravity type foundations will lead to the largest quantities of sediment spill, and as the level of disturbance from service and construction ships the assessment has been based on the worst case scenario with gravity foundations. The assessment is split into localized habitat displacement caused by disturbance from vessels and habitat change caused by reductions in available food supply due either to direct (excavation) or indirect (sediment dispersal) effects of the construction works.

8.1 Habitat displacement

The distribution models on the three key species of wintering waterbirds in the region revealed that only the Long-tailed Duck winters in the area of the Kriegers Flak OWF in relatively high densities, and only low densities of waterbirds winter along the route of the cable trace. Hence, in terms of the general avoidance of the wind farm construction site this species will suffer more than Common and Velvet Scoter which occur in very low densities at the site. Table 24 gives estimates of numbers displaced using the 3 km disturbance distance (wind farm footprint plus 3 km buffer) and modelled mean densities during 2008-2010. Only few Common and Velvet Scoters are estimated to become displaced, whereas between 730 and 1300 Long-tailed Ducks may be displaced.

As the density of Long-tailed Ducks wintering in the region has declined by almost a factor 10 since the early 1990’es the potential for a larger degree of displacement than presently assessed cannot be ruled out. Yet, given the short duration of the disturbance and the size of the current population of wintering Long-tailed Ducks in the Baltic Sea (1,482,000, Skov et al. 2011) the extent of the displacement impact will be minor. Displacement impacts on waterbirds along the route of the cable trace are assesses as negligible.

Table 24. Estimated mean density (n/km^2) and number of wintering waterbirds displaced from the Kriegers Flak OWF due to disturbance from construction vessels. Estimates are based on modelled distribution for the period 2008-2010 and a disturbance distance of 3 km (footprint and buffer 302 km^2).

	Mean density	Total	STD
Long-tailed Duck	2.42	732	572
Velvet Scoter	0.0120	4	3
Common Scoter	0.0845	26	23

8.2 Habitat impairment and destruction

The construction of the Kriegers Flak using gravity foundations as well as the placement of the cable to Rødvig are assessed to have minor impacts on the feeding habitats of waterbirds in the area of Kriegers Flak and along the route of the cable trace. Disturbance effects on potential benthic prey organisms living in the construction site have been assessed as being limited (ATR 7). Sediment dispersal affecting available food supplies of benthic invertebrates and fish was estimated to be small-scale (ATR 7 and 8), and even if concentrations of suspended material are estimated to exceed 10 mg/l during periods of the construction the sediment plumes will be of short duration with no risk for affecting feeding conditions of diving waterbirds for more than a few hours.

Judged from the density models the potential habitat loss for feeding birds due to the construction of foundations will amount to less than 0.1% of the available habitat in the Kriegers Flak area.

8.3 Assessment of the severity of impacts during construction

Tabel 25 below shows the assessment of the effect of the construction activities.

Table 25. Overall effect of the construction activities on birds.

Birds – Construction phase					
Source Type Receptor	**Degree of disturbance**	**Importance**	**Likelihood**	**Duration**	**Extend of impact**
Long-tailed Duck/ **Disturbance from boats**	High	Local	High	Short-term	Minor
Argument	Displace-ment from feeding habitat	Total number affected amounts to < 1 ‰ of Baltic population	High number of boats in prime habitat	Disturb-ance from single boats will last maxi-mum few hours	Due to low number af-fected
Long-tailed Duck/ **Habitat impair-ment/ destruction**	High	Low	Low	Short-term	Negligible
Argument	Potential loss of food resources	Very localised	Too short pe-riod with dense sedi-ment plumes to affect mussels	Very short term	Short term

9 Assessment of effects on birds in the operation period

9.1 Habitat displacement

The spatial scale of the effect of habitat displacement due to the disturbance from the turbine structures of the Kriegers Flak OWF will be comparable to the scale of displacement due to disturbance from vessels, i.e. 3 km including footprint. Hence, the displacement area will be the same (302 km^2) and the annual number of displaced Long-tailed Ducks at the same level as during the construction phase.

Table 26 gives estimates of numbers displaced using the 3 km disturbance distance and modelled mean densities during 2008-2010. Only single Common and Velvet Scoters are estimated to become displaced, whereas between 160 and 1300 Long-tailed Ducks may be displaced annually.

As the density of Long-tailed Ducks wintering in the region has declined by almost a factor 10 since the early 1990'es the potential for a larger degree of displacement than presently assessed cannot be ruled out. As the operation period may last 20 years or more, the total effect of habitat displacement during operation will be larger (moderate extent) than during construction, even if the affected number amounts to less than 1 ‰ of the total population of wintering Long-tailed Ducks in the Baltic Sea, and therefore is insignificant at the population level.

Table 26. Estimated mean density (n/km^2) and number of wintering waterbirds displaced from the Kriegers Flak OWF due to disturbance from the wind farm footprint. Estimates are based on modelled distribution for the period 2008-2010 and a disturbance distance of 3 km (buffer 302 km^2).

	Mean density	Total	STD
Long-tailed Duck	2.42	732	572
Velvet Scoter	0.0120	4	3
Common Scoter	0.0845	26	23

9.2 Habitat impairment and destruction

Even if the area of feeding habitat loss due to the foundations can be compensated for by scour protection, seaducks may not be able to utilise mussel beds on the scour protection. The reduction of the biomass of mussels in the wind farm due to a reduction in the flow velocity over the seabed caused by the foundations and structures was assessed at small (ATR 7), yet at a higher level than the impact due to direct habitat change. However, the foundations of the Kriegers Flak OWF are expected to physically cover an area of less than 0.1% of the total wind farm area in which the turbines are placed. Therefore, the habitat loss caused by direct and indirect physical changes is expected to be insignificant to birds.

9.3 Artifical reef effect

With respect to artificial reef effects on birds the changes in benthos diversity and biomass as well as fish abundance are expected to be less pronounced in the coarser sediments at Kriegers Flak OWF than at Horns Rev, but comparable to Nysted, where the scour protection was introduced into a benthic environment which was already influenced by coarse sediments and stones. No significant changes in the numbers of feeding waterbirds were recorded following the construction of the Nysted OWF, and similarly no artificial reef effects on birds are expected for the Kriegers Flak OWF.

9.4 Collision risk

9.4.1 Common Crane

The Swedish and Norwegian populations of Common Crane are estimated to 75,000 and 9,000 individuals, respectively. Of these, all 84,000 birds are expected to cross the Arkona Basin (Swedish University of Agricultural Sciences Pers. Comm.). This is also supported by the work by Swanberg (1985) in the eighties, where autumn migration directions for migrating Common Crane in Sweden were assessed, through radio and TV inquiries, to almost entirely southerly migration direction during autumn in all places of southern Sweden. However, assuming Common Crane are using all parts of the corridor west of Bornholm equally only 13% are expected to cross Kriegers Flak OWF on average during autumn, which is equal to 10,920 Common Crane. The 13% corresponds to the proportional area occupied by the two wind farm lay-out areas of the Kriegers Flak OWF.

The baseline and behavioural investigations from FINO 2 and the coastal sites in southern Sweden and eastern Denmark provided evidence that the flight height of Common Crane at Kriegers Flak depends on the wind conditions. Despite these weather-induced variations in the collision risk, the behavioural investigations at the Baltic 2 offshore wind farm clearly indicated that the vast majority of Common Crane cross Kriegers Flak at altitudes between 50 and 200 m (Figure 96).

Low level of responsive behaviour to the perimeter of offshore wind farms (macro avoidance rate of 0.07) was recorded at the Baltic 2 wind farm; a type of behaviour which is similar to the one reported for Cormorants. In addition, an open corridor of at least 5 km width will be located between the two lay-out parts which may be perceived by the Common Crane as a zone of no or limited risk of collision. Here, it should be noted that macro avoidance behaviour of Common Crane at Baltic 2 was only recorded for 14 flocks. Yet, based on the homogenous flight pattern of the tracks of these flocks as they approached the wind farm from the south (

Figure 94) it is not expected that a larger sample size would change the recorded macro avoidance although the rotors were idling. These results are in contrast to the experiences of Common Crane avoidance in relation to land-based wind farms. Strong reactions of Common Crane to land-based wind farms have been indicated by the avian collision statistics from the German county of Brandenburg which listed only 1 Common Crane casualty as compared to for instance 99 Red Kites (Dürr 2008). Collision risk estimates from other offshore wind farms are not available.

Relatively strong horizontal and vertical meso avoidance behaviour of Common Crane (combined rate of 0.64) was recorded at the Baltic 2 wind farm. This means that although the majority of Common Crane seem to enter the wind farm without hesitation two of three flocks will avoid crossing the rotor swept zone. This rate is still clearly lower than the rate recommended by Krijgsveld et al. (2011) for seabirds at 0.976. Vertical meso avoidance by Common Crane has also been documented by the post-construction monitoring at Utgrunden in Kalmarsund. This program provided observations of three flocks of Common Crane approaching the wind farm during autumn migration (Pettersson 2005). Of these none showed evasive horizontal manoeuvers, yet all three flocks passed above the height of the rotors. One flock initially approached at rotor height, yet was able to take height by soaring in front of the wind farm.

In order to derive estimates of 'baseline' collision mortality the predicted annual number of collisions of Common Cranes for Kriegers Flak (216-296 Common Crane per year depending on turbine type) was combined with the collision mortality for the established Baltic 1 (2.3 MW) and Baltic 2 (3.6 MW) wind farms (150 Common

Crane per year). The combined estimated 'baseline' and Kriegers Flak related mortality of Common Crane amounts to between 366 (8 MW) and 446 (4 MW) birds per year (Figure 105). The predicted annual number of casualties for the remaining turbine types fall within this range.

Compared to the international PBR threshold of 1887 birds, using the lowest value for at stable population following the precaution principle, the impact for the baseline and Kriegers Flak wind farms will be below 50% of the PBR threshold. The collision impact on Common Crane is therefore rated as minor.

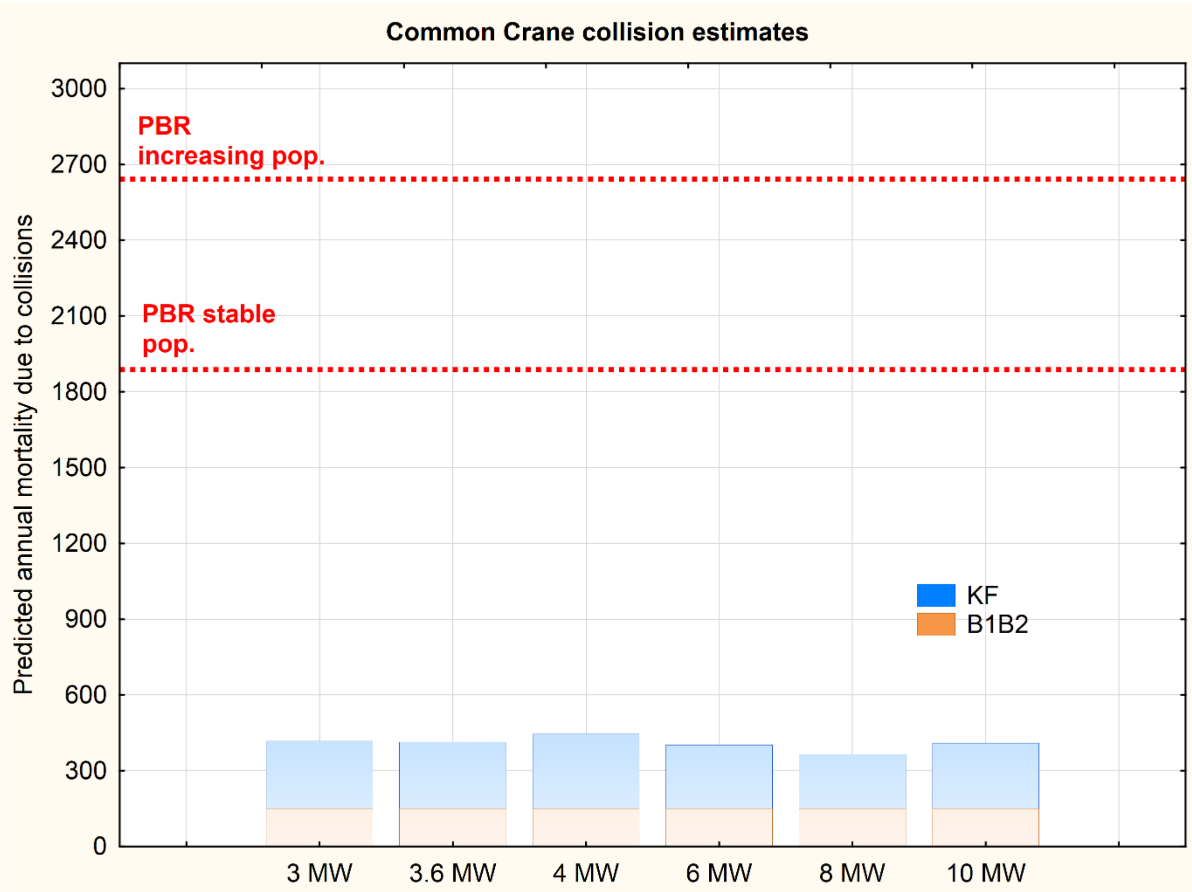


Figure 105. Number of Common Crane predicted to collide annually for six different types of wind turbines (Kriegers Flak in combination with Baltic 1 and Baltic 2 offshore wind farms). The PBR threshold for a stable and increasing population is indicated.

9.4.2 **Honey Buzzard**

The number of Honey Buzzards leaving the Falsterbo peninsular each autumn is estimated to 7,500 individuals. Of these, 202 birds are expected to cross the Arkona Basin, but of these only 18% are expected to cross Kriegers Flak OWF, which is equal to 36 Honey Buzzards. For the wind farm design including 10 MW turbines the proportion of Honey Buzzards flying in altitudes swept by the turbine blades amounted to 100%. All in all, 2 Honey Buzzards are predicted to collide per autumn with the turbines at the proposed wind farm at Kriegers Flak. Compared to the international PBR threshold of 1050 birds, the impact would constitute a very low level (Table 27. S). Hence, the risk of impact at population level is considered below a level which could cause adverse effects on the affected Honey Buzzard population.

Table 27. Species specific PBR thresholds and predicted annual collision number of raptors for the 10 MW layout assuming a macro avoidance rate of -0.35.

Species	PBR threshold	Annual collision number
Honey Buzzard	1050	2
Common Buzzard	9000	12
Rough-legged Buzzard	1400	2
Marsh Harrier	400	1
Osprey	710	1
Red Kite	390	1
Kestrel	2655	1
Sparrowhawk	14600	10
Harriers	217	2
Peregrine/Hobby/Merlin	173/273/6440	1

9.4.3 **Common Buzzard**

The number of Common Buzzards leaving the Falsterbo peninsular each autumn is estimated to 14,000 individuals (Karlsson et al. 2004). Of these, 840 birds are expected to cross the Arkona Basin, but of these only 18% are expected to cross Kriegers Flak OWF, which is equal to 147 Common Buzzards. A satellite tagging-study of Common Buzzards showed that this species mainly migrate via an eastern route over Sealand, and thus, that only a small fraction of the individuals migrate straight south over the Ankona Basin in the Baltic Sea (Strandberg et al. 2009). For the wind farm design including 10 MW turbines the proportion of Common Buzzards flying in altitudes swept by the turbine blades amounted to 100%. All in all, 12 Common Buzzards are predicted to collide per autumn with the turbines at the proposed wind farm at Kriegers Flak. Compared to the international PBR threshold, the impact would constitute a very low level of the PBR threshold of

9000 birds. Hence, the risk of impact at population level is considered below a level which could cause adverse effects on the affected Common Buzzard population.

9.4.4 Rough-legged Buzzard

The number of Rough-legged Buzzards leaving the Falsterbo peninsular each autumn is estimated to 930 individuals (Karlsson et al. 2004). Of these, 120 birds are expected to cross the Arkona Basin, but of these only 18% are expected to cross Kriegers Flak OWF, which is equal to 21 Rough-legged Buzzards. For the wind farm design including 10 MW turbines the proportion of Rough-legged Buzzards flying in altitudes swept by the turbine blades amounted to 100%. All in all, 2 Rough-legged Buzzards are predicted to collide per autumn with the turbines at the proposed wind farm at Kriegers Flak. Compared to the international PBR threshold, the impact would constitute a very low level of the PBR threshold of 1400 birds. Hence, the risk of impact at population level is considered below a level which could cause adverse effects on the affected Rough-legged Buzzard population.

9.4.5 Kestrel

The number of Kestrels leaving the Falsterbo peninsular each autumn is estimated to 475 individuals (Karlsson et al. 2004). Of these, 90 birds are expected to cross the Arkona Basin, but of these only 18% are expected to cross Kriegers Flak OWF, which is equal to 16 Kestrels. For the wind farm design including 10 MW turbines the proportion of Kestrels flying in altitudes swept by the turbine blades amounted to 100%. All in all, 1 Kestrel is predicted to collide per autumn with the turbines at the proposed wind farm at Kriegers Flak. Compared to the international PBR threshold, the impact would constitute a very low level of the PBR threshold of 2655 birds. Hence, the risk of impact at population level is considered below a level which could cause adverse effects on the affected Kestrel population.

9.4.6 Marsh Harrier

The number of Marsh Harriers leaving the Falsterbo peninsular each autumn is estimated to 550 individuals (Karlsson et al. 2004). Of these, 50 birds are expected to cross the Arkona Basin, but of these only 18% are expected to cross Kriegers Flak OWF, which is equal to 9 Marsh Harriers. For the wind farm design including 10 MW turbines the proportion of Marsh Harriers flying in altitudes swept by the turbine blades amounted to 100%. All in all, 1 Marsh Harrier is predicted to collide per autumn with the turbines at the proposed wind farm at Kriegers Flak. Compared to the international PBR threshold, the impact would constitute a very low level of the PBR threshold of 1400 birds. Hence, the risk of impact at population level is considered below a level which could cause adverse effects on the affected Marsh Harrier population.

9.4.7 Osprey

The number of Ospreys leaving the Falsterbo peninsular each autumn is estimated to 241 individuals (Karlsson et al. 2004). Of these, 40 birds are expected to cross the Arkona Basin, but of these only 18% are expected to cross Kriegers Flak OWF, which is equal to 7 Ospreys. A satellite-tracking study on Swedish ospreys have elucidated that these birds are migrating over a broad front during autumn, with some individuals taking a eastern route over Sealand and others flying straight south over the Arkona Basin in the Baltic Sea (Alerstam et al. 2006). For the wind farm design including 10 MW turbines the proportion of Ospreys flying in altitudes swept by the turbine blades amounted to 100%. All in all, 1 Osprey is predicted to collide per autumn with the turbines at the proposed wind farm at Kriegers Flak. Compared to the international PBR threshold, the impact would constitute a very low level of the PBR threshold of 710 birds. Hence, the risk of impact at population level is considered below a level which could cause adverse effects on the affected Osprey population.

9.4.8 Red Kite

The number of Red Kites leaving the Falsterbo peninsular each autumn is estimated to 500 individuals (Karlsson et al. 2004). Of these, 60 birds are expected to cross the Arkona Basin, but of these only 18% are expected to cross Kriegers Flak OWF, which is equal to 11 Red Kites. For the wind farm design including 10 MW turbines the proportion of Ospreys flying in altitudes swept by the turbine blades amounted to 100%. All in all, 1 Red Kite is predicted to collide per autumn with the turbines at the proposed wind farm at Kriegers Flak. Compared to the international PBR threshold, the impact would constitute a very low level of the PBR threshold of 390 birds. Hence, the risk of impact at population level is considered below a level which could cause adverse effects on the affected Red Kite population.

9.4.9 Sparrowhawk

The number of Sparrowhawks leaving the Falsterbo peninsular each aut umn is estimated to 16,000 individuals (Karlsson et al. 2004). Of these, 800 birds are expected to cross the Arkona Basin, but of these only 18% are expected to cross Kriegers Flak OWF, which is equal to 140 Sparrowhawks. For the wind farm design including 10 MW turbines the proportion of Sparrowhawks flying in altitudes swept by the turbine blades amounted to 98.7%. All in all, 10 Sparrowhawks is predicted to collide per autumn with the turbines at the proposed wind farm at Kriegers Flak. Compared to the international PBR threshold, the impact would constitute a very low level of the PBR threshold of 14600 birds. Hence, the risk of impact at population level is considered below a level which could cause adverse effects on the affected Sparrowhawk population.

9.5 Barrier effect

Masden et al. (2009) showed, for migrating diving ducks, that the present situation of offshore wind power generation in the Baltic Sea have a non-significant and trivial impact compared with the total costs of a migration episode of 1400 km. However, the authors pay attention to the possible future cumulative effects on the population from the construction of further wind farms along the migration route in the years to come, an impact that may be especially important when considered in combination with other human actions (Drewit & Langston 2008).

The Kriegers Flak OWF will be located centrally in the 100 km wide expanse of sea between Germany and Sweden. Large numbers of seaducks are likely to use this area én route between the wintering areas in the Danish Straits-North Sea and their breeding grounds. Although the spatial characteristics of the waterbird migration have not been mapped in detail it is most likely that the migration occurs over a broad front with weak tendencies for aggregations along the coasts of Sweden and Germany. Depending on the lay-out chosen, the cross-sectional diameter of the wind farm will span roughly 20% of the width of the Arkona Basin, and consequently barrier effects on migrating waterbirds are likely to be small.

9.6 **Assessment of the severity of impacts during operation**

Table 28 below shows the assessment of the effect of the operation activities.

Table 28. Overall effect of the operation activities on birds (following page).

Birds – Operation phase					
Source Type Receptor	**Degree of disturbance**	**Importance**	**Likelihood**	**Duration**	**Extend of impact**
Long-tailed Duck/ **Disturbance from tur-bines**	High	Local	High	Long-term	Moderate
Argument	Displace-ment from feeding habitat	Total number affected amounts to < 1 ‰ of Baltic population	High number of boats in prime habitat	Disturbance from OWF will last at least 20 years	Due to long period of du-ration
Long-tailed Duck/ **Habitat impair-ment/ destruction**	High	Low	Low	Short-term	Negligible
Argument	Potential loss of food resources	Very localised	Small area	Long term	Localised
Raptors/ **Collision**	High	Low	Low	Long-term	Negligible-minor
Argument	Mortality	Small numbers compared to reference pop-ulations	Small numbers		
Common Crane/ **Collision**	High	Low	High	Long-term	Minor
Argument	Mortality	Small to large numbers com-pared to refer-ence popula-	High number passing		

Birds – Operation phase					
Source Type Receptor	**Degree of disturbance**	**Importance**	**Likelihood**	**Duration**	**Extend of impact**
		tion			
Passerines/ Collision	High	Low	High	Long-term	Negligible-minor
Argument	Mortality	Low numbers compared to reference populations	Large numbers		
Waterbirds/ Collision	High	Low	Low	Long-term	Negligible-minor
Argument	Mortality	Low numbers compared to reference populations	Strong avoidance	Long-term	Negligible-minor
Waterbirds/ Barrier effect	Low	Low	High	Long-term	Negligible-minor
Argument	Extra energy expenditure	Relatively small extra energy expenditure	Strong avoidance	Long-term	Negligible-minor

10 Assessment of effects on migrating bats

Few monitoring studies of migrating bats at offshore wind farms have yet been carried out. This assessment which is mainly based on the studies by Ahlén (2002, 2003, 2006), Bach & Rahmel (2004) and Ahlén et al. (2009) should therefore be seen as qualitative. Only minor disturbance effects from vessels are envisaged during construction, yet during operation of the wind farm collision risks are obviously pertinent. Although no bat casualties at offshore wind farms have yet been documented, migrating bats can be attracted by the turbine blades and towers if and when insects are gathered there (Ahlén et al. 2009). A behavioural feature of migrating bats at sea may be the change in flight altitude when bats change from low altitude flights commonly recorded at sea to flying at higher altitude close to the turbine (Ahlén et al. 2009).

The above-mentioned studies have also shown that both migrating and resident species may search and hunt insects close to some offshore turbines. Similar to what seems to be the case with respect to birds of prey, there are no indications that bats avoid turbines offshore.

The lack of documented casualties may simply be explained by lack of possibilities to detect or measure incidents. It is worth noting that detection ranges of acoustic bat recorders are limited to 1-50 m depending on species, thus collection of data on responsive movements and attraction is very constrained.

Light conditions at offshore turbines may affect the behavior of bats. If strong light on the turbines are prescribed, this could increase the attraction of insects and thereby the hunting activity of bats (Rydell & Baagøe 1996a, 1996b).

The risk for population-level effects of collisions is probably only an issue where bats are concentrated close to migration corridors, e.g. outside take-off points on coastlines or at preferred feeding areas out at sea. The risk for casualties is most probably smaller where bats only pass on a biannual migration and not are attracted by insects. Thus, the extent of collision impacts on migrating bats are assessed as moderate if migration corridors for these species are in the central part of the Arkona Basin are of regional importance. In all other cases the extent of the impact is assessed as low.

Article 12 of the Council Directive 92/43/EEC on the protection of species states that member states shall take the requisite measures to establish a system of strict protection for bats as all species are listed in Annex IV. This entails prohibition of all forms of deliberate capture or killing of specimens, deliberate disturbance of these species, particularly during the period of breeding, rearing, hibernation and migration and deterioration or destruction of breeding sites or resting places. Concerning the deliberate killing, despite the fact that collision events and mortality of bats cannot be ruled out, it is not expected that the project would cause mortalities for which a violation of Article 12 of the Habitats Directive would be expected.

10.1 **Assessment of the severity of impacts on bats**

Table 29 below shows the assessment of the effect on migrating bats.

Table 29. Overall effect of the wind farm on migrating bats. **Bats**					
Source Type Receptor	**Degree of disturbance**	**Importance**	**Likelihood**	**Duration**	**Extend of impact**
Bats/ **Disturbance from boats**	Medium	Local	Low	Temporary	Negligible
Argument	Displacement due to in-creased ship activity	Locally around boa ts	Depends on use of strong lights		
Bats/ **Collision with wind-mill**	High	Local-regional	Medium	Long term	Low-moderate
Argument	Mortality	Broad front migration Large popu-lations of recorded species with favourable conservation status	Regular mi-gration occur throughout autumn and spring	Long term	Depends on size and re-cruitment of affected populations

11 Assessment of effects of decommissioning

Impacts on staging and migrating birds envisaged during decommissioning are similar to some of the disturbance impacts expected during construction, depending on the activities of removal of foundations and service boats.

Vessel operations associated with removal of superstructures will result in short-term disturbance of Long-tailed Ducks and other waterbirds wintering in the area. Gravitational foundations will require considerable effort to remove, and may require the use of explosives which could lead to disturbance of more birds. As during the construction works the temporal and spatial scale of disturbance of waterbirds during decommissioning is expected to be short and the extent of impact minor.

The removal of foundations will cause dispersal of sediments into the water column, and periods with elevated concentrations of suspended sediments should be envisaged. Due to expected small scale of sediment plumes and short duration of the spills the effect on mussels and other prey organisms for wintering waterbirds is judged as very small.

11.1 Assessment of the severity of impacts during decommissioning

The results of the impact assessment of a possible dismantling of the wind farm are assessed in Table 30. The effects on wintering waterbirds are judged as negligible to minor. No information is available regarding expected number of service boats and quantities of sediments spilled when removing different types of foundations. Thus differences in the level of impacts between foundation types cannot currently be assessed.

Table 30. Overall effect of decommissioning the wind farm on birds.

Birds – Construction phase					
Source Type Receptor	**Degree of disturbance**	**Importance**	**Likelihood**	**Duration**	**Extend of impact**
Long-tailed Duck/ **Disturbance from boats**	High	Local	High	Short-term	Minor
Argument	Displace-ment from feeding habitat	Total number affected amounts to < 1 ‰ of Baltic population	High number of boats in prime habitat	Disturb-ance from single boats will last maxi-mum few hours	Due to low number af-fected
Long-tailed Duck/ **Habitat impair-ment/ destruction**	High	Low	Low	Short-term	Negligible
Argument	Potential loss of food resources	Very localised	Too short pe-riod with dense sedi-ment plumes to affect mussels	Very short term	Short term

12 Cumulative effects

Several wind farms are planned in the region of Kriegers Flak, of which four has been consented and eight has been submitted or are in the process of submitting consent applications to the Danish, Swedish and German planning authorities (Table 31). Once built, each of these 12 wind farms will inevitably cause additive mortality to Common Cranes migrating between Germany and Sweden due to collisions. However, estimating collision risks for these wind farms confidently is hampered by the lack of details available concerning wind farm design and turbine type. Thus, a relatively crude estimate of the cumulative impact had to be undertaken assuming the use 3.6 MW turbines for all of the 12 wind farms.

Using the Band (2012) collision model, the cumulative collision impacts on Common Cranes from the consented four German projects with the Danish Kriegers Flak, Baltic 1 and Baltic 2 projects (Table 31, Tier 1 and2) were assessed as moderate as the total predicted annual mortality caused by collisions (1,112-1,192) would constitute 60% of the PBR threshold for a stable population (Figure 106). If all 12 planned and consented projects with Kriegers Flak and the existing Baltic 1 and 2 projects would be built (Table 31, Tier 1-3) the annual cumulative collision impact on Common Crane would be very large (2,620-2,700) or at the PBR level for an increasing population (Figure 106). Hence, the wind farms may cause an annual mortality which cannot be sustained by the Swedish-Norwegian breeding population.

Thus, the cumulative impact may have a significant effect on the population development of the species, and may cause the Swedish-Norwegian population to suffer a long-term decline. Cumulative collision impacts on other species are assessed as minor, albeit uncertainties exist regarding the number of raptors crossing the Arkona region during spring migration. Cumulative habitat displacement impacts on waterbirds from are assessed as minor, as displacement impacts on Long-tailed Ducks will be at a similar level (< 1000 birds annually) for the Swedish and German sites at Kriegers Flak.

Table 31. Overview of offshore wind farm projects included in the cumulative impact assessment.

Consenting phase	Wind farm	Country	Assessment tier	Total planned MW	Total planned WTGs
Tier 1					
Operational	Baltic I	Germany	1	48.3	21
Under construction	Baltic II	Germany	1	288	80
Tier 2					
Consent authorized	Kreigers Flak II	Sweden	2	640	128
Consent authorized	Arcadis Ost 1	Germany	2	348	58
Consent authorized	Wikinger	Germany	2	350	70
Consent authorized	Arkona-Becken Sudost	Germany	2	385	60
Tier 3					
Consent submitted	Wikinger Nord	Germany	3	40	8
Consent submitted	Baltic Power	Germany	3	500	80
Consent submitted	Adlergrund 500	Germany	3	72	20
Consent submitted	Ostseeschatz	Germany	3	225	45
Consent submitted	Strom-Nord	Germany	3	270	45

Consent submitted	Baltic Eagle	Germany	3	415	83
Consent submitted	Ostseeperle	Germany	3	245	35
Concept/Early Planning	Kriegers Flak	Denmark	3	600	200

- Tier 1- Projects operational or under construction;
- Tier 2- Projects with consent authorised; and
- Tier 3- Projects with planning application submitted.

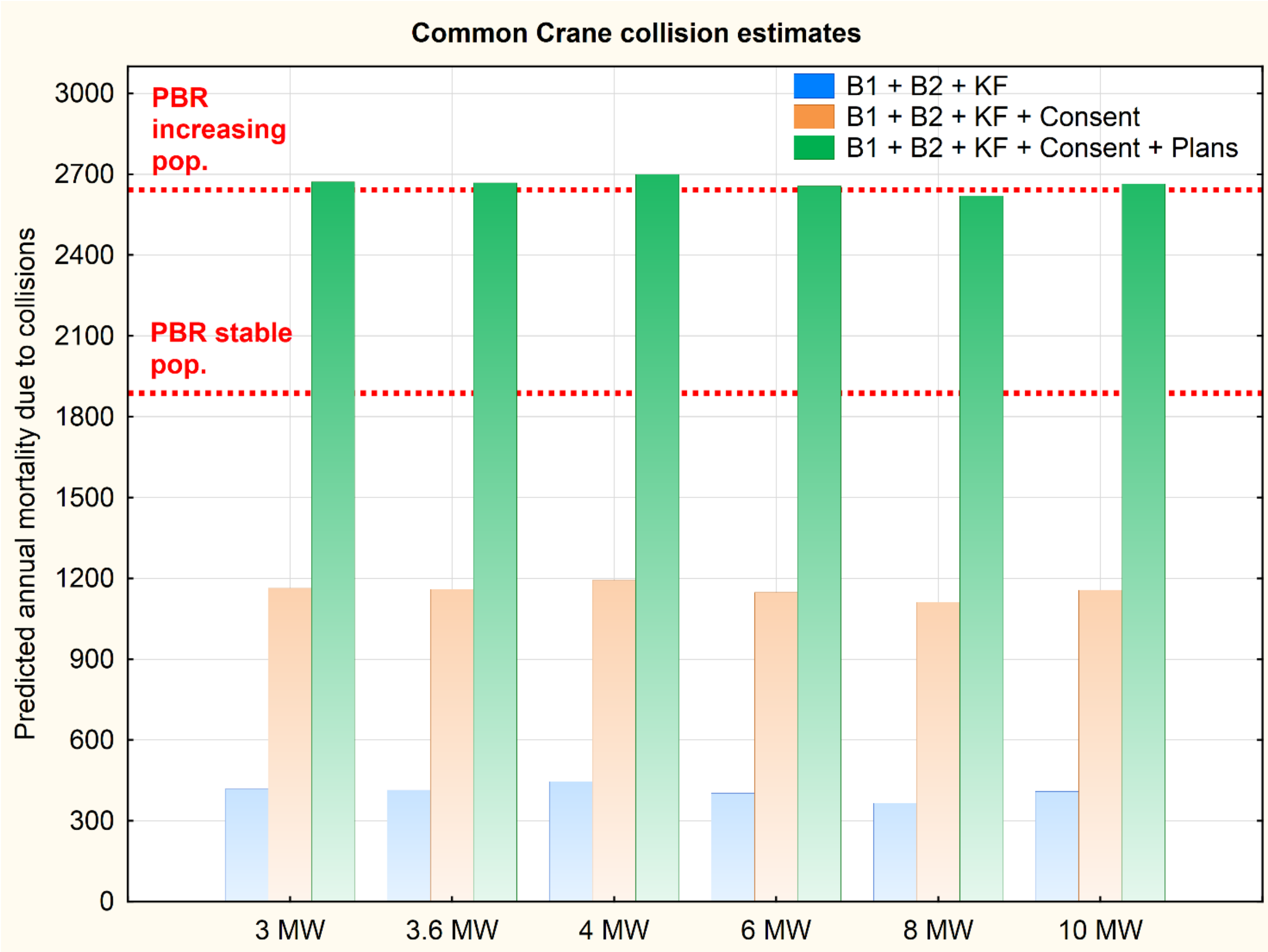


Figure 106. The cumulative number of Common Crane predicted to collide for six different types of wind turbines (Kriegers Flak in combination with Baltic 1 and Baltic 2 offshore wind farms (baseline mortality) compared to baseline and all consented wind farms and baseline and all consented and planned wind farms in the Arkona region. The PBR threshold for both a stable and increasing population of Common Crane are indicated.

13 Natura 2000 screening

As the Kriegers Flak projects is only assessed to pose minor impacts on migrating Common Crane the Natura 2000 screening only covers the cumulative collision risk from all planned and consented wind farm projects with Kriegers Flak. No Natura 2000 areas designated for protection of birds (SPAs) are located in the vicinity of the planned Kriegers Flak wind farm. However, as the entire Swedish-Norwegian population of Common Crane is migrating across the Arkona Basin during their spring and autumn migration collisions with the Kriegers Flak wind farm and the two existing wind farms and 12 other wind farms planned and consented in the region potential possess a risk to the long-term health of this population. The Common Crane is listed on Annex I of the EC Birds Directive on the conservation of wild birds (79/409/EEC), and the EU member states are therefore obliged to protect the species during migration as well as during breeding.

Being long-distance migrants, Common Crane from the Swedish-Norwegian population regularly use several sites located along the flyway route between Scandinavia and Spain. Many of these sites have been designated as SPAs on account of the number of Common Crane staging and wintering at the sites. Long-term reductions in the population of migrating Common Crane crossing the Arkona Basin would obviously affect the number of Common Crane using these SPAs, and hence adverse effects on the integrity of these sites may not be discounted. This may be the case even if only the consented wind farms and Kriegers Flak are built, as the predicted added mortality due to collisions with the wind farms would constitute 60 % of PBR for a stable population.The assessment of impacts on Natura 2000 sites concludes with respect to migrating Common Crane that although there is no indication of Likely Significant Effect (LSE) from Kriegers Flak OWF alone or with the existing Baltic 1 and 2 wind farms, an adverse effect arising from in-combination collision risk, associated with the operational phase of Kriegers Flak OWF, Baltic 1 OWF, Baltic 2 OWF and the 4 consented other wind farms in the region cannot be precluded. The same conclusion is made with respect to in combination impacts with the 8 other planned wind farms in the region.

14 Transboundary effects

According to the Espoo Convention on Environmental Impact Assessment in a transboundary context and EU Directive 85/337/EEC, transboundary environmental impacts cannot be excluded for the Kriegers Flak offshore wind farm. This is primarily related to the collision of Common Crane (see Chapter 12-13).

The Espoo Convention aims to prevent, mitigate and monitor environmental damage by ensuring that transboundary environmental factors are explicitly considered before a decision is made as whether to approve a proposed project. The Espoo Convention requires the identification and communication of potential transboundary impacts to relevant stakeholders via the application of an impact assessment.

15 Mitigation measures

There is a paucity of detailed knowledge on mitigation measure which can effectively minimise the potential collision risk to Common Crane crossing the Kriegers Flak. However, a design measure which may reduce collision risks would be to design the lay-out of the turbine rows so they align with the mean vector of the corridor used by Common Crane – or approximately 170°/10°.

Another rather more efficient means for reducing the collision risk would be to implement mitigation and detection systems based on radars and cameras/observers which would inform when movements of Common Crane are approaching the wind farms during the well-defined periods of crane migration. Rather than implementing expensive stops during predefines periods, such real-time detection systems could be used to limit wind production stops to the actual situations when Cranes are approaching the wind farm and collision risk is imminent.

16 Data limitations or knowledge that might affect the assessment

16.1 Existing conditions

Due to factors beyond the control of this project baseline investigations from the FINO platform could not start before August 2014. As a consequence, data on movements of Common Crane and raptors during spring migration were only collected from the coastal areas of eastern Denmark and Sweden, including the

Falsterbo Rev Lighthouse. These data proved useful to describe changes in flight altitude as a function of distance to departure coast. Historic data clearly show that Common Crane also pass the area in spring, whereas knowledge about the migration intensities of raptors during spring is quite limited (IfAÖE 2003, Kube et al. 2004b).

The flight patterns of Common Crane and raptors found during the baseline investigations of this project were unambiguous as they documented descending flight altitudes with distance from departing coast, causing the majority of birds to perform low-altitude flight as they crossed Kriegers Flak. As these patterns will be similar during spring when the birds depart from northern coast of Germany descending trends will also cause Common Crane and raptors to reach low altitude over Kriegers Flak during spring. From available knowledge it is clear that almost all Swedish Common Crane also cross the Arkona Basin during spring. Greater uncertainty exists regarding the number of raptors which regularly cross Kriegers Flak in spring. Even if the number of raptors crossing Kriegers Flak in spring is unlikely to be at a level which would alter the assessment of collision risks for raptors, the predicted number of casualties based on the autumn migration may still be regarded as a minimum.

16.2 **Assessment of effects**

Although the collision risks for raptors and Common Crane were mainly predicted based on the empirical study on Common Crane responses to Baltic 2 during spring 2015 the calculations using the Band (2012) collision model are still based on several assumptions worth consideration.

The proportion trying to cross the swept zone without showing evasive behaviour to rotor blades was set to 92%, i.e. a micro avoidance rate of 8%, following Winkelman (1992). Despite several wind farm monitoring programs have been undertaken, no data on micro-avoidance of different species have yet been published. However, the actual collision rate depends to some extent on this parameter, and variations of 10 % in the parameter would result in 20-fold differences in the resulting collision risk. Thus, the collection of real species-specific avoidance rates must be regarded as a priority if robust estimates of collisions are to be established.

The probability of being hit by the rotor-blades 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 been made by the Band model. For example, the bird is assumed to be of simple cruciform shape, with the wings at the halfway point between nose and tail. The turbine blade is assumed to have a width and a pitch angle, but to have no thickness, and it is assumed that a bird's flight will be unaffected by a near miss, despite the slipstream around a turbine blade. Most uncertainty seems to be related to the assumption that birds always cross the turbine at 90 degrees, even for birds which approach the rotor obliquely. The logic behind this, which is not founded on field observations, is that the reduction in crossed area and increase in time it takes for the bird to cross the rotor plane during oblique approaches probably cancel each other out. Certainly, empirical data are needed to enable comparisons of collision rates during perpendicular and oblique crossings. These may, conveniently, be collected from land-based wind farms.

It should be stressed that the collision predictions for Common Crane rest on two assumptions which if proven wrong could cause the number of collisions to increase above the PBR threshold. First of all, it was assumed that the Common Crane during both spring and autumn migration would disperse throughout the

Arkona Basin. Accordingly, even if Kriegers Flak is located centrally on the route between southern Sweden and Rügen the site would not have a higher density of flying Common Crane than other parts of the region. The PBR threshold has been established assuming no important anthropogenic mortality on the population. Important sources of mortality which may lower the PBR threshold would include habitat changes and collisions with power lines.

17 Conclusion and recommendations

17.1 Collected baseline data

The baseline investigations in relation to the planned wind farm on Kriegers Flak provided an unprecedented amount of information on flight patterns of different species of raptors and Common Crane across the western Baltic Sea. The results strongly indicate that the flight altitudes close to the coast are largely dependent on the weather conditions with most species loosing height at closer distances to the coast during poor visibility and head winds. These results are comparable to the results of the investigation of raptor migration across central Kattegat collected as part of the baseline for the Anholt offshore wind farm (Skov et al. 2012). At larger distances from the coast, the results of the Kriegers Flak baseline documented that the vast majority of raptors and Common Crane fly at relatively low altitudes (< 200 m) during all weather conditions when they cross Kriegers Flak. Despite these general observations and model results, observations from FINO 2 also show that some variations in the flight patterns exist, and both Common Crane and raptors are occasionally seen flying above rotor height or very low (potentially below rotor height).

The collected data on flight patterns also provided strong evidence from migration directions at the south Swedish coast and from the numbers of birds observed at the FINO 2 platform that small proportions of raptors actually cross the Arkona Basin. During an average autumn 40-50,000 raptors and 84,000 Common Crane leave Skåne on their southward migration. For most species of raptors, less than 10% of the birds leaving Skåne cross the Arkona Basin. However, slightly larger proportions are seen for Osprey, harriers and falcons. Hence, although the overall conclusion regarding the geography of raptor migration through the Western Baltic in autumn is that the large majority of birds pass open sea at least 25 km north of Kriegers Flak, several protected and prioritized species with small populations like Peregrine Falcon and Hobby regularly pass the area. Here, it should be noted that a larger proportion of raptors may pass the Arkona Basin during spring.

17.2 Generalisation of baseline results

Impact assessments are increasingly undertaken under relatively high time pressure. As a consequence, assessments often have to be undertaken on the basis of data collected only during one year. This raises concerns regarding the general applicability of the assessments, especially in marine environments where distributions of habitats and species are prone to significant inter-annual variability (Skov et al. 2012). The risk of unparsimonious assessments of the Kriegers Flak project in relation to birds was offset in two ways; by extensive use of historic data, and by application of spatial models capable of generalising distributions along both environmental and time gradients.

For waterbirds historic data were applied to demonstrate decadal changes in the habitat use of key species of waterbirds in the region. For bird migration, data from OWF baseline studies in the region were used to describe temporal and altitude patterns of non-raptors. For Common Crane use of historic weather data made it possible to assess the mean wind conditions which the Common Crane face during their southward migration in autumn.

The application of habitat models for waterbirds made it possible to generalize patterns through couplings to benthic habitat features over time, including potential mussel growth. Likewise, the application of flight models for bird migration enabled generalisations to be made through couplings to weather conditions and landscape features. The waterbird models showed a highly stabile use of Kriegers Flak, despite large changes in densities of Long-tailed Ducks over the past 15 years. Hence, predicted impacts in relation to total populations wintering in the Baltic Sea should be regarded as very robust.

Flight models showed that despite weather-dependence in flight altitude and angle of descend during crossing of the Arkona Basin, the vast majority of raptors and Common Crane will be flying at rotor height for the 4 – 10 MW layouts, with significant collision rates predicted for Common Crane. Only the 3 MW and 3.6 MW layouts make it possible for most of the Common Crane (55% and 51%, respectively) to pass Kriegers Flak above rotor height. The use of historic wind data enabled the mean collision rates for Common Crane at Kriegers Flak to be predicted for head wind and tail wind situations, respectively.

17.3 Uncertainty of impact assessment

The use of predictive modelling provided quantitative measures of uncertainty in relation to both baseline and impact assessments. Low standard errors of waterbird predictions for the Kriegers Flak area, and high standard errors in the deeper parts of the Arkona Basin were apparent. Hence, overall the assessments of low-moderate habitat displacement impacts on Long-tailed Ducks should be regarded as safe.

The application of flight models ensured that predicted collision rates could be associated with indications of the degree of uncertainty of predictions. As no or very little autocorrelation was left in the model residuals the low degree of uncertainty can be judged as indications of good confidence in the model predictions, and hence predicted collision rates.

The assessment in relation to bats should be seen as qualitative due to the nature of the data collected, and the lack of detection range and quantitative information. Whether future studies will make it possible to make assessments on bats based on more quantitative data depends on the development of innovative methods with improved detection of bats. Development of survey techniques is also a prerequisite for collection of unbiased monitoring data on behavioural responses to bats.

18 References

Ahlén, I. 2002. Fladdermöss och fåglar dödade av vindkraftverk. Fauna och flora 97:3: 14–22.

Ahlén, I. 2003. Wind turbines and Bats – a pilot study. Final report to the Swedish National Energy Agency 11 December 2003. Dnr 5210P-2002-00473, P-nr P20272-1.

Ahlén, I. 2006. Gotlands fladdermusfauna 2005. Länsstyrelsen Gotlands län, Rapporter om natur och miljo¨ 2006(2): 1–30. [Summary: The bat fauna of Gotland 2005.]

Ahlén, I. , Baagøe, H.J. & Bach, L. 2009. Behavior of scandinavian bats during migration and foraging at sea. Journal of Mammalogy, 90(6): 1318–1323.

Alerstam, T. 1990. Bird migration. Cambridge University Press, Cambridge, UK.

Alerstam, t., Hake, M. & Kjellen, N. 2006. Temporal and spatial patterns of repeated migratory journeys by ospreys. Animal Behaivour 71: 555-566.

Alerstam, T., Rosén, M. Bäckman, J., Ericson, P.G.P. & Hellgren, O. 2007. Flight speeds among bird species: allometric and phylogenetic effects. PLoS Biology 5(8): e197. doi: 10.1371/journal.pbio.0050197 (open source).

Baagøe, H. J. 2007. Alle kapitler om flagermus. PP. 40-99: H. J. Baagøe & T. S. Jensen: Pattedyratlas. Gyldendal.

Bach, L. & U. Rahmel. 2004. Überblick zu Auswirkungen von Windkraftanlagen auf Fledermäuse – eine Konfliktabschätzung – Bremer Beiträge für Naturkunde und Naturschutz Band 7: 245-252.

Band, W. 2000. Windfarms and birds: Calculating a theoretical collision risk assuming no avoidance. SNH Guidance. Excel spreadsheet available: http://www.snh.gov.uk/docs/C234672.xls.

Band, W., 2012. Using a collision risk model to assess bird collision risks for offshore windfarms, s.l.: The Crown Estate.

Band, W., Madders, M. and Whitfield, D.P. 2007. Developing field and analytical methods to assess avian collision risk at windfarms. In De Lucas, M., Janss, G. and Ferrer, M. (eds) 'Birds and Wind Power'. www.quercus.pt

Bellebaum, J., A. Diederichs, J. Kube, A. Schulz & G. Nehls (2006): Flucht-und Meidedistanzen überwinternder Seetaucher und Meeresenten gegenüber Schiffen auf See. Ornithologischer Rundbrief Mecklenburg-Vorpommern 45: 86–90.

Bellebaum, J., Grieger, C., Klein, R., Köppen, U., Kube, J., Neumann, R., Schulz, A., Sordyl, H. and Wendeln, H. 2010. Ermittlung artbezogener Erheblichkeitsschwellen von Zugvögeln für das Seegebiet der südwestlichen Ostsee bezüglich der Gefährdung des Vogelzuges im Zusammenhang mit dem Kollisionsrisiko an Windenergieanlagen. Abschlussbericht. Forschungsvorhaben des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit (FKZ 0329948). Neu Broderstorf.

Bevanger, K. et al. 2009. Pre-and post-construction studies of conflicts between birds and wind turbines in coastal Norway. NINA Report no. 505. 70 pp.

Blew, J., Hoffmann, M., Nehls, G. & Hennig, V., 2008. *Investigations of the bird collision risk and the responses of harbour porpoises in the offshore wind farms Horns Rev, North Sea, and Nysted, Baltic Sea, in Denmark. Part I: Birds,* s.l.: German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

Cook, A.S.C.P., Humphreys, E.M., Masden, E. A. & Burton, N.H.K. 2014. The avoidance rates of collision between birds and offshore turbines. BTO Research Report No. 656.

Desholm, M. 2006. Wind farm related mortality among avian migrants – a remote sensing study and model analysis. PhD thesis, Univeristy of Copenhagen. 127 pp.

Desholm, M. 2009. Avian sensitivity to mortality: prioritising migratory bird species for assessment at proposed wind farms. Journal of Environmental Management, 90, 2672-2679.

Desholm, M., Fox, A.D., Beasley, P. & Kahlert, J. 2006. Remote techniques for counting and estimating the number of bird-wind turbine collisions at sea: a review. Ibis 148: 76-89.

Desholm, M. & Kahlert, J. 2005. Avian collision risk at an offshore wind farm. Biology Letters 1: 296-298.

Dietz, C., Halversen, O.,V. & N. Dietmar. 2007. Bats of Britain, Europe & Northwest Africa: A & C Black Publishers Ltd.

Dillingham, P.W. and Fletcher, D. 2008. Estimating the ability of birds to sustain additional human-caused mortalities using a simple decision rule and allometric relationships. Biological Conservation, 141, 1783–1792.

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

Durinck, J., Skov, H., Jensen, F.P. & Pihl, S. 1994. Important Marine Areas for Wintering Birds in the Baltic Sea. EU DG XI research contract no. 2242/90-09-01. Ornis Consult report.

Dürr, T. 2008. Vogelverluste an Windenergieanlagen in Deutschland. Daten aus der zentralen Fundkartei der Staatlichen Vogelschutzwarte im Landesumweltamt Brandenburg. Stand: 01. September 2008. Landesumweltamt Brandenburg.

Energinet.dk. 2014. Technical project description for the largescale offshore wind farm (600 MW) at Kriegers Flak. August 2014.

Garthe, S. 2003. Erfassung von Rastvögeln in der deutschen AWZ von Nord- und Ostsee. Abschlussbericht für das F+E-Vorhaben FKZ: 802 85 280 - K 1 (Bundesamt für Naturschutz). Forschungs- und Technologiezentrum Westküste.68 pp.

Gill, J.P., Sales, D., Pinder, S. & R. Salazar. 2008. Draft Kentish Flats wind farm fifth ornithological monitoring report. ESS 2008.

IfAÖ (2003): Environmental Impact Study for the Construction of the “Kriegers Flak” Offshore Wind Park

Kahlert, J., Laubek, B., Aaen, K., Waagner, S., Groom, G., Andersen, P.N. 2011. Rødsand 2 Offshore Wind Farm Post-construction Studies on Migrating Land Birds autumn 2010. Grontmij/CarlBro, National Environmental Research Institute.

Karlsson, L. et al. 2004. Vingar över Falsterbo. Pilelandet, Falsterbo.

Krijgsveld, K.L., Fijn, R.C., Japink, M., van Horssen, P.W., Heunks, C., Collier, M.P., Poot, M.J.M., Beuker, D., Dirksen, S. 2011. Effect Studies Offshore Wind Farm Egmond aan Zee: Flux, flight altitude and behaviour of flying birds. Report nr.: 10-219 / OWEZ_R_231_T1_20111110_flux&flight. Commissioned by NoordzeeWind. Bureau Waardenburg bv, The Netherlands.

Kube, J. et al. 2004a. Rastande sjöfåglar vid Kriegers Flak, Sverige. Institut für Angewandte Ökologie GmbH. For Sweden Offshore Wind AB.

Kube, J. et al. 2004b. Flyttande fåglar vid Kriegers Flak, Sverige. Institut für Angewandte Ökologie GmbH. For Sweden Offshore Wind AB.

Leif Nilsson 2004 .. skal være Leif Nilsson pers. comm.

Leopold, M.L., van Bemmelen, R.S.A. & Zuur, A.S. 2012. Responses of Local Birds to the Offshore Wind Farms PAWP and OWEZ off the Dutch mainland coast. IMARES Report number C151/12.

Masden, E. A., Haydon, D. T., Fox, A. D., Furness, R. W., Bullman, R., and Desholm, M. 2009. Barriers to movement: impacts of wind farms on migrating birds. ICES Journal of Marine Science 66: 746–753.

Masden, E. A., Haydon, D. T., Fox, A. D., Furness, R. W. M. 2010. Barriers to movement: modelling energetic costs of avoiding marine wind farms amongst breeding seabirds. Marine Pollution Bulletin 60: 1085-1091.

Milner-Gulland, E.J. & Akçakaya, H.R. 2001. Sustainability indices for exploited populations under uncertainty. Trends in Ecology and Evolution 16: 686-692.

Naturvårdskonsult Gerell 2011. Fladdermös i Skåne, Rapport 2011:9. Länsstyrelsen i Skåne.

Niel, C. and Lebreton, J.D. 2005. Using demographic invariants to detect over-harvested bird populations from incomplete data. Conservation Biology, 19, 826–835.

Petersen, I.K., Pihl, S., Hounisen, J.P., Holm, T.E., Clausen, P., Therkildsen, O. & Christensen, T.K. 2006a: Landsdækkende optællinger af vandfugle, januar og februar 2004. Danmarks Miljøundersøgelser. 76 s. – Faglig rapport fra DMU nr. 606.

Petersen et al. 2006b. Final results of bird studies at the offshore wind farms at Nysted and Horns Rev, Denmark. Report request. Commissioned by DONG energy and Vattenfall A/S. National Environmental Research Institute. Ministry of the Environment, Denmark.

Petersen, I.K., Nielsen, R.D., Pihl, S., Clausen, P., Therkildsen, O., Christensen, T.K., Kahlert, J. & Hounisen, J.P. 2010. Landsdækkende optælling af vandfugle i Danmark, vinteren 2007/2008. Danmarks Miljøundersøgelser, Aarhus Universitet. 78 s. – Arbejdsrapport fra DMU nr. 261.

Petersen, I.K., Nielsen, R.D. & Mackenzie, M.L. 2014. Post-construction evaluation of bird abundances and distributions in the Horns Rev 2 offshore wind farm area, 2011 and 2012. Report commissioned by DONG Energy. Aarhus University, DCE – Danish Centre for Environment and Energy. 51 pp.

Petterson, J. 2003. Vårflyttningen av sjöfåglar över Kriegers Flak i sydvästra Östersjön. JP Fågelvind. For Sweden Offshore Wind AB.

Plonczkier, P. & Simms, I.C. 2012. Radar monitoring of migrating pink-footed geese: behavioural responses to offshore wind farm development. Journal of Applied Ecology 49: 1187-1194.

PMSS, 2007. Annual FEPA Monitoring Report (2005-6). March 2007. North Hoyle Offshore Wind Farm. PMSS.

R Development Core Team. 2004. A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org

Rioux, S., Savard, J.-P. L. & Gerick, A. A. 2013. Avian mortalities due to transmission line collisions: a review of current estimates and field methods with an emphasis on applications to the Canadian electric network. Avian Conservation and Ecology 8(2): 7.

Rydell, J., & Baagøe, H.J. 1996a: Bats and streetlamps. Bat conservation International, 14, nr 4. pp.10-13. Austin, Texas, ISSN: 1049-0043.

Rydell, J., & Baagøe, H.J. 1996b: Gatlampor ökar fladdermössens predation på fjärilar. (Streetlamps increase bat predation on moths). Ent. Tidskr. 117 (4): pp. 129-135.

Schwemmer, P., B. Mendel, N. Sonntag, V. Dierschke & S. Garthe (2011): Effects of ship traffic on seabirds in offshore waters: implications for marine conservation and spatial planning. Ecol. Appl. 21: 1851-1860.

Shono, H.,2008. Application of the Tweedie distribution to zero-catch data in CPUE analysis, Fish. Res., doi:10.1016/j.fishres.2008.03.006

Skov, H. et al. 2011. Waterbird Populations and Pressures in the Baltic Sea. TemaNord 2011: 550. Nordic Council of Ministers. 229 pp.

Skov, H., Jensen, N.E., Durinck, J., Jensen, B.P. & Leonhard, S. 2009. Rødsand 2 wind farm. Monitoring of landbird Migration - Baseline Studies autumn 2008. Report DHI and Orbicon. 35 p.

Skov, H., Heinänen, S., Jensen, N., Durinck, J., & Johansen, T. 2012. Rødsand 2 Offshore Wind Farm Post Construction. Post Construction Studies on Migrating Red Kite/Landbirds. DHI. Report commissioned by E.ON Sweden.

Stefansson, G. 1996. Analysis of groundfish survey abundance data: combining the GLM and delta approaches. ICES Journal of Marine Science, 53: 577-588.

Strandberg, R., Alerstam, T., Hake, M. & Kjellen, N. 2009. Short-distance migration of the Common Buzzard *Beteo buteo* recorded by satellite tracking. Ibis 151: 200-206.

Swanberg. P.O. c. 1985. Migration routes of Swedish Common Cranes (Grus grus) present knowledge. Link: http://epa.uz.ua/01600/01603/00075/pdf/Aquila_EPA-01603_1986-1987_063-073.pdf

Taylor, B.L., Wade, P.R., DeMaster, D.P., and Barlow, J. 2000. Incorporating uncertainty into management models for marine mammals. Conservation Biology, 14, 1243–1252.

Thiel, M., Nehls, G., Bräger, S. and Meissner, J. 1992. The impact of boating on the distribution of seals and moulting ducks in the Wadden Sea of Schleswig-Holstein Publ. Ser. Neth. Inst. Sea Res., 20, 221-233.

Wade, P.R. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. Marine Mammal Science, 14, 1–37.

Wetlands International. 2012. Waterbird Population Estimates online databasehttp://wpe.wetlands.org/

Winkelman, J.E. 1992. De invloed van de Sep-proefwindcentrale te Oosterbierum (Friesland) op vogels, 1: Aanvaringsslachtoffers. RIN-rapport 92/2, IBN-DLO, Arnhem, The Netherlands.

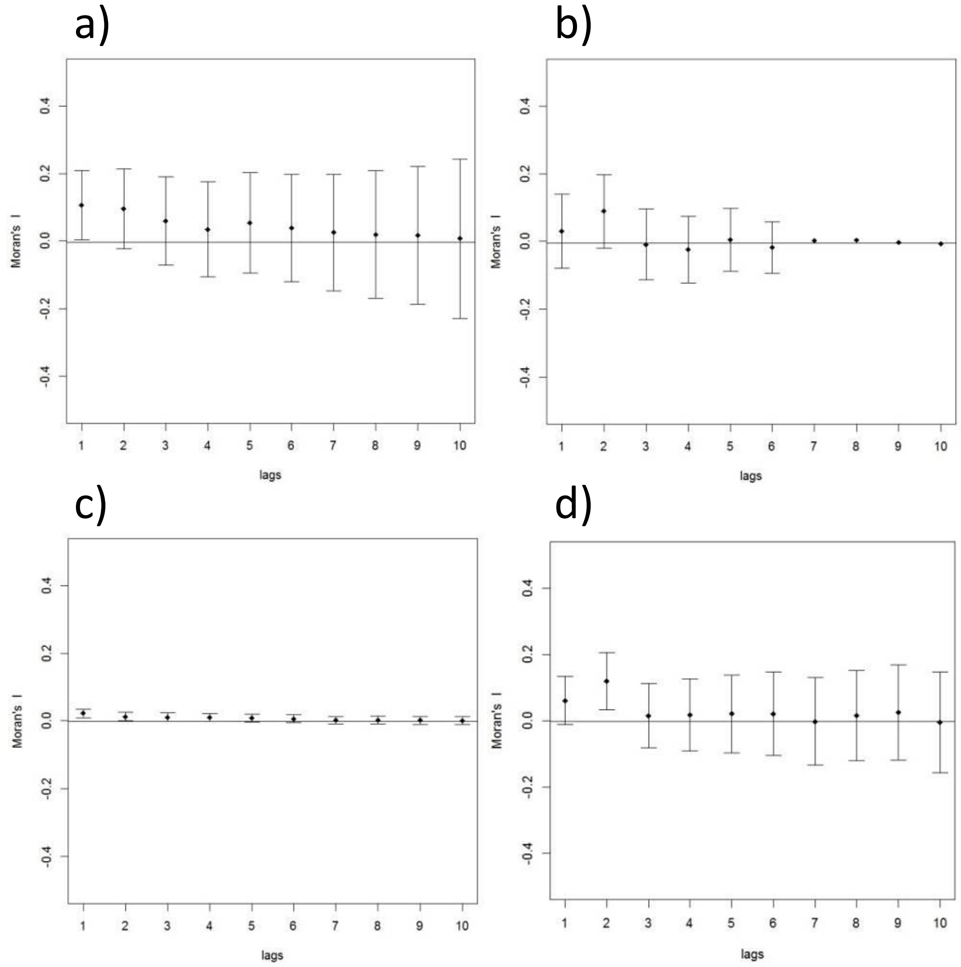
Wood, S. N. 2006. Generalized Additive Models: An Introduction with R. Chapman and Hall, London.

Zuur, A.F., Ieno, E.N., Walker, N., Saveliev, A.A. and Smith, G.M. 2009. Mixed Effects Models and Extensions in Ecology with R. Springer, Berlin, 524 pp.

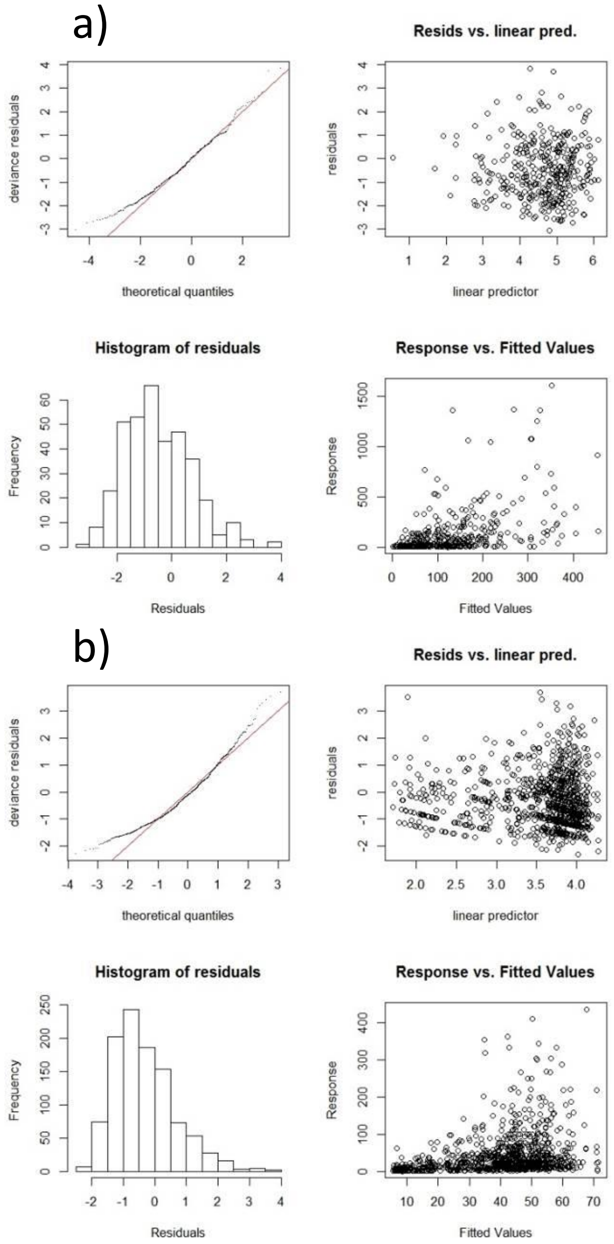
APPENDICES

APPENDIX A – Distribution model diagnostics and predictions

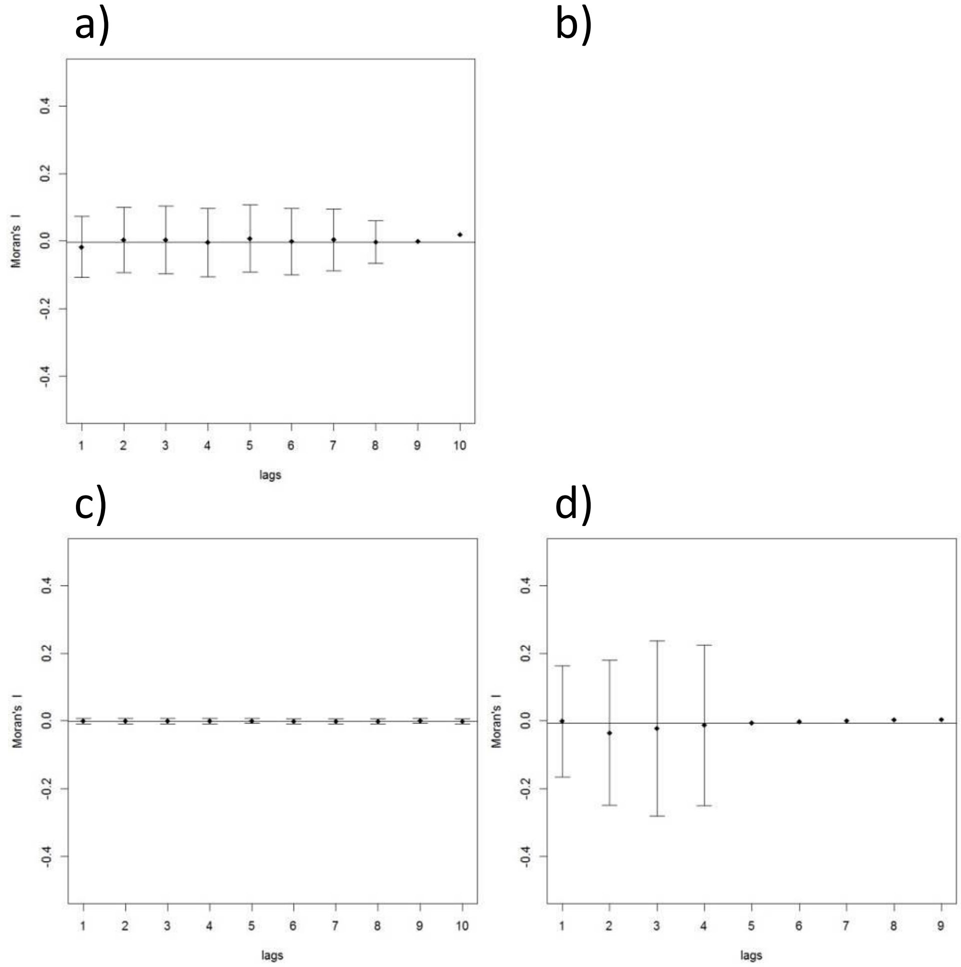
A1 Diagnostic plots for the seaduck distribution models



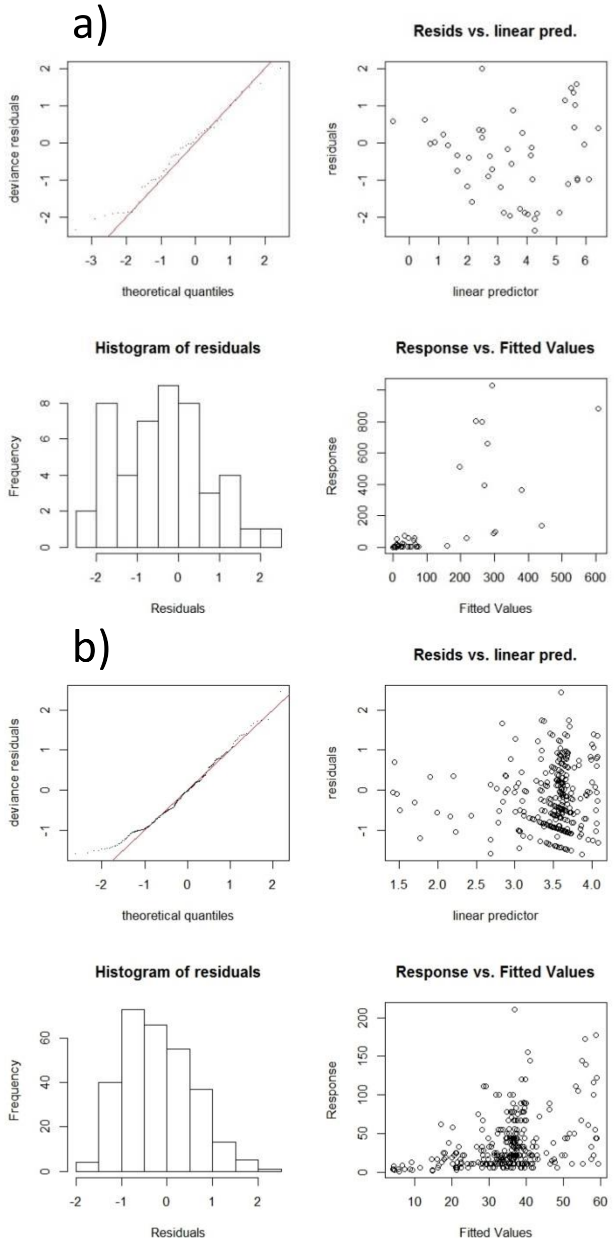
Spatial autocorrelograms of the model residuals for Long-tailed ducks a) presence/absence period 1, b) positive period 1, c) presence/absence period 2, d) positive period 2. The dots indicate the estimated Moran's I and the bars the square root of the variance of the estimates. One lag equals in Period 1 = 2500 m and in Period 2 = 1000.



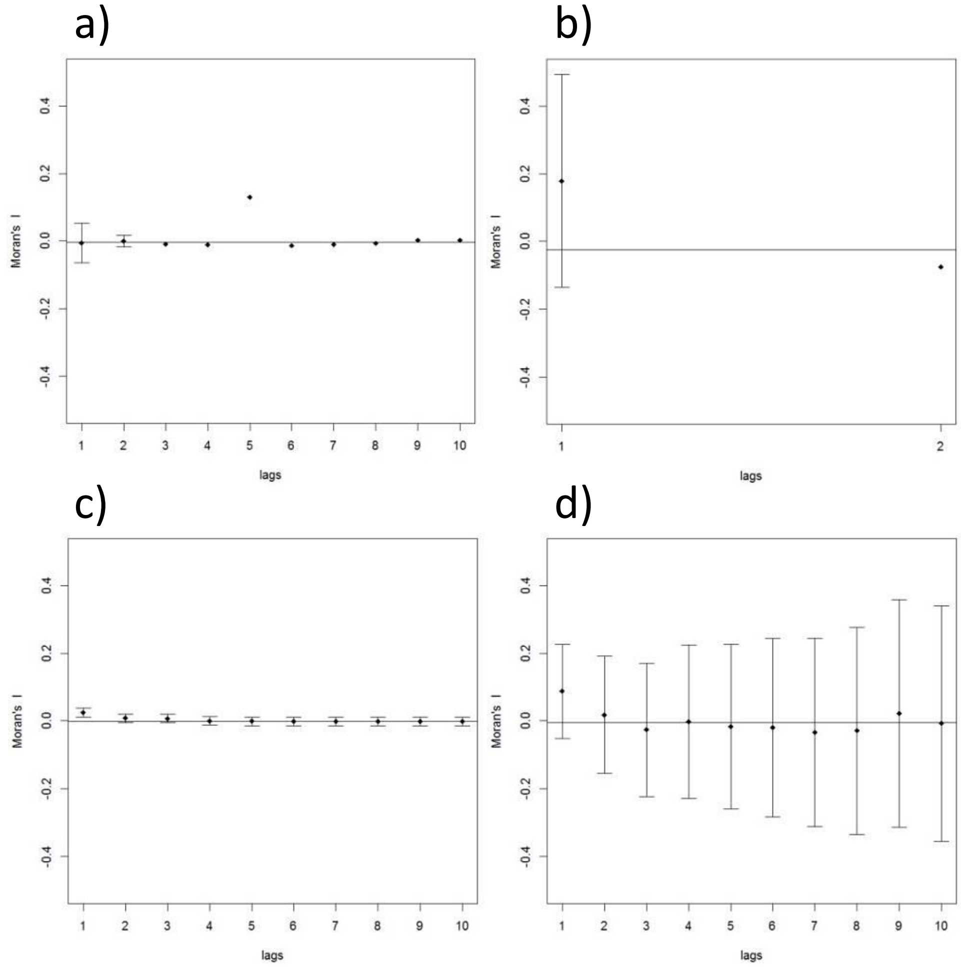
Diagnostic plots for the positive parts of the models for Long-tailed duck during a) Period 1 and b) Period 2. Normality of the residuals is displayed in the graphs to the left. The spread of the residuals are visualised in the upper right and the observed against predicted values in the lower right plot.



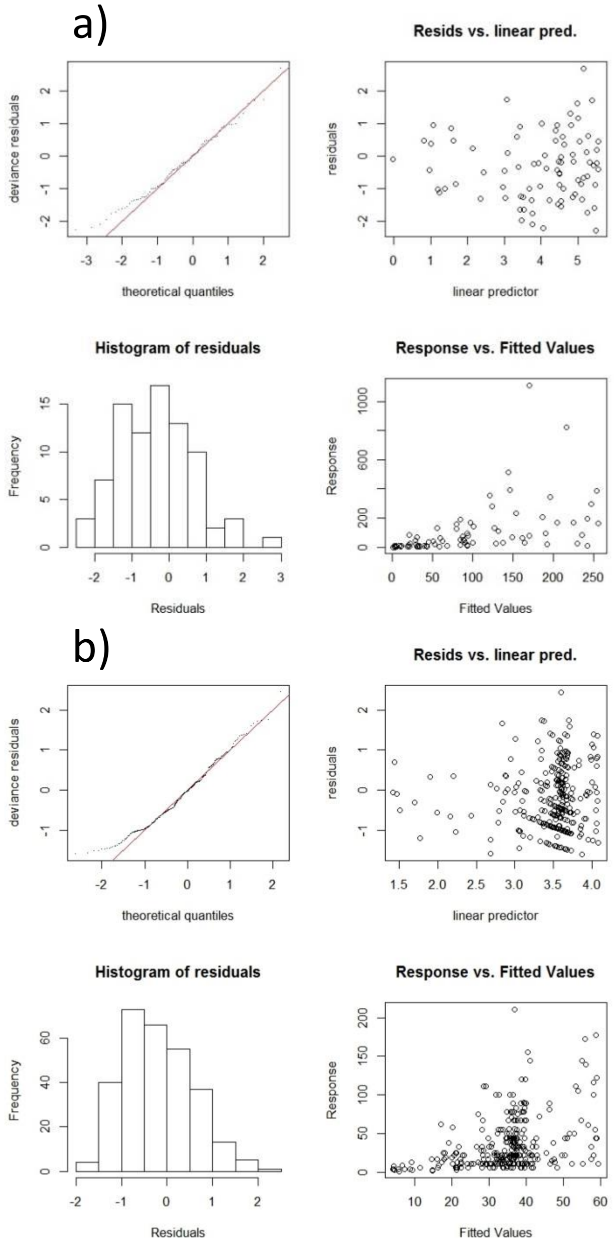
Spatial autocorrelograms of the model residuals for Common Scoter a) presence/absence period 1, b) not enough samples (positive period), 1 c) presence/absence period 2, d) positive period 2. The dots indicate the estimated Moran's I and the bars the square root of the variance of the estimates. One lag equals in Period 1 = 2500 m and in Period 2 = 1000.



Diagnostic plots for the positive parts of the models for Common Scoters during a) Period 1 and b) Period 2. Normality of the resilduals is displayed in the graphs to the left. The spread of the residuals are visualised in the upper right and the observed against predicted values in the lower right plot.

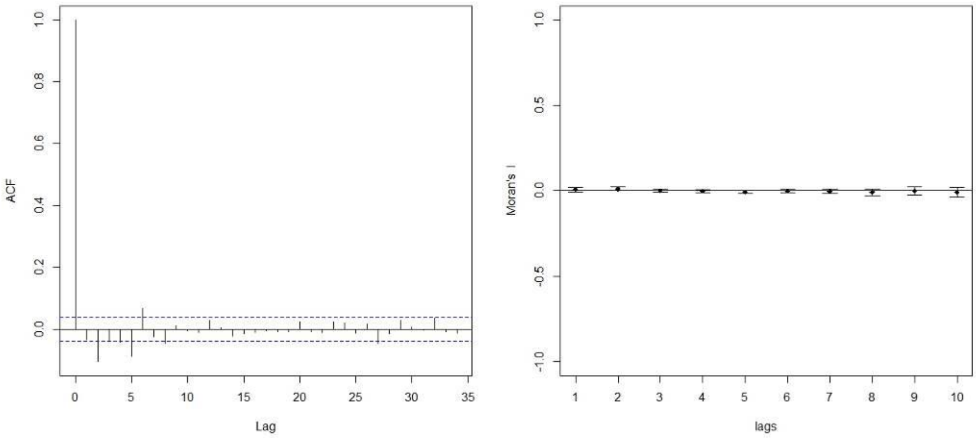


Spatial autocorrelograms of the model residuals for Velvet Scoters a) presence/absence period 1, b) positive period 1, c) presence/absence period 2, d) positive period 2. The dots indicate the estimated Moran's I and the bars the square root of the variance of the estimates. One lag equals in Period 1 = 2500 m and in Period 2 = 1000.

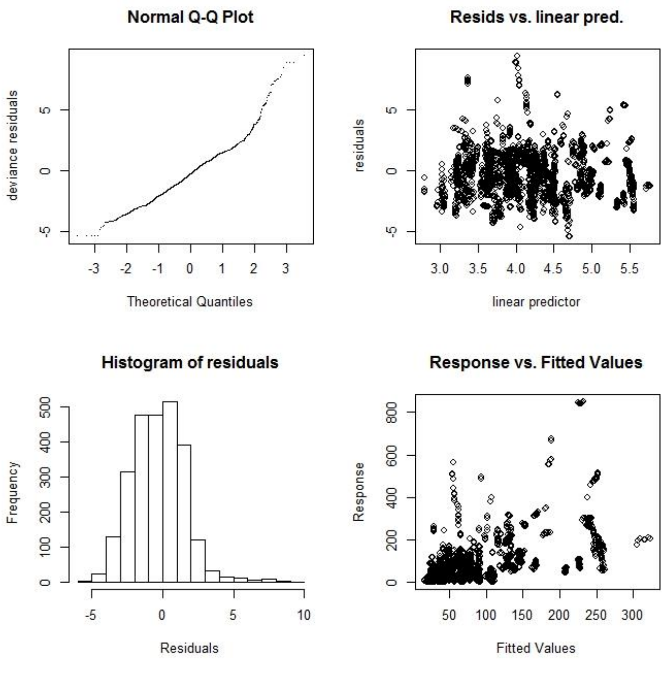


Diagnostic plots for the positive parts of the models for Velvet Scoters during a) Period 1 and b) Period 2. Normality of the resilduals is displayed in the graphs to the left. The spread of the residuals are visualised in the upper right and the observed against predicted values in the lower right plot.

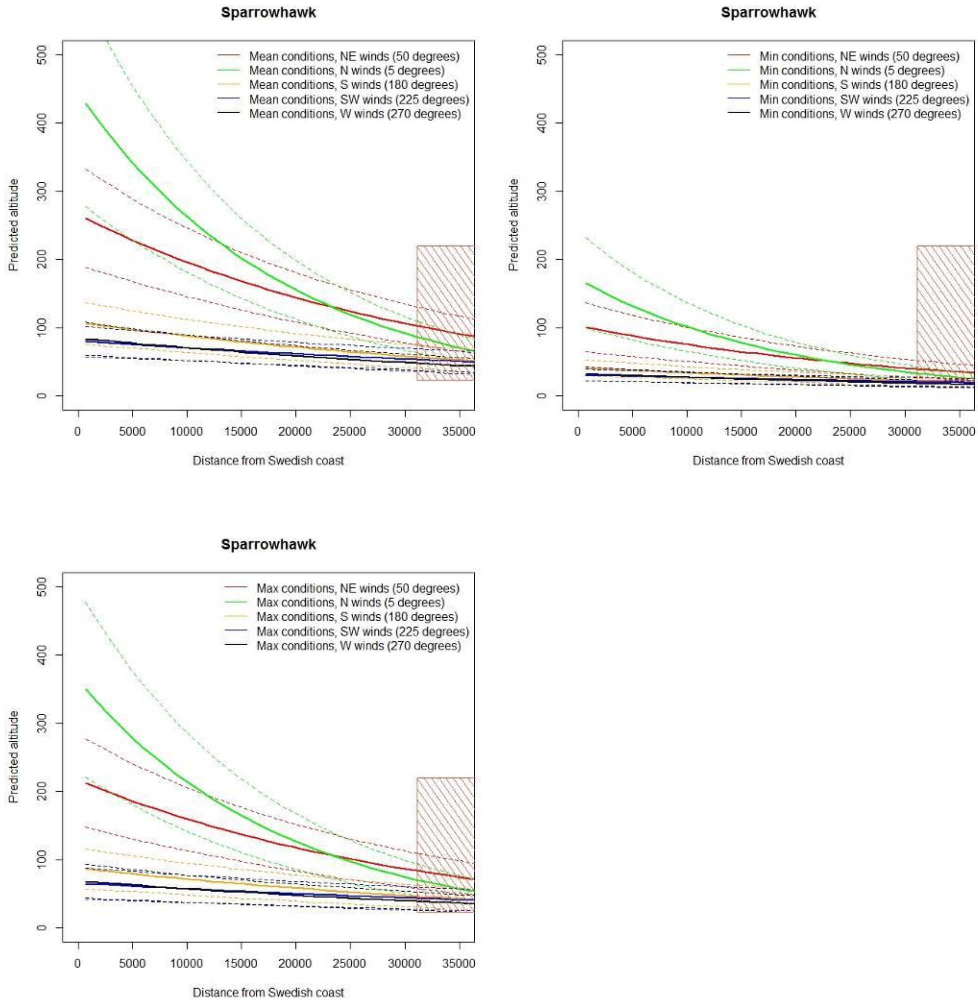
A2 Diagnostic and prediction plots for the altitude GAMMs



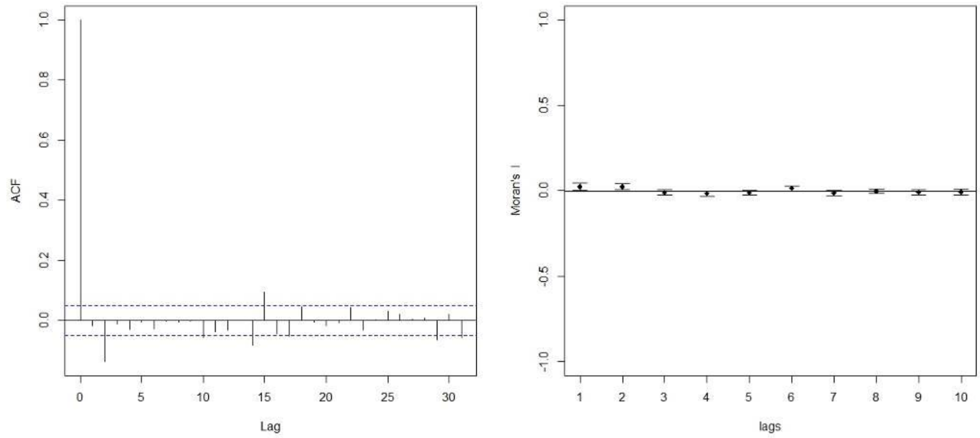
Serial (to the left) and spatial autocorrelation (to the right) in the residuals of the lme part of the GAMM for the Sparrowhawk. 1 lag =250m in correlogram (to the right) and the bars indicate the square root of the estimated Moran's I value.



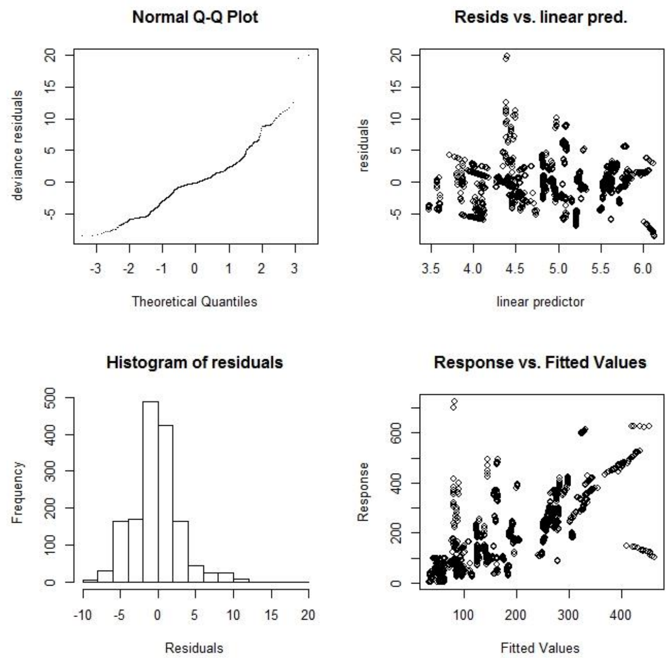
Diagnostics of the gam part of the GAMM for the Sparrowhawk. Normality of the residuals is displayed in the graphs to the left. The spread of the residuals are visualised in the upper right and the observed against predicted values in the lower right plot.



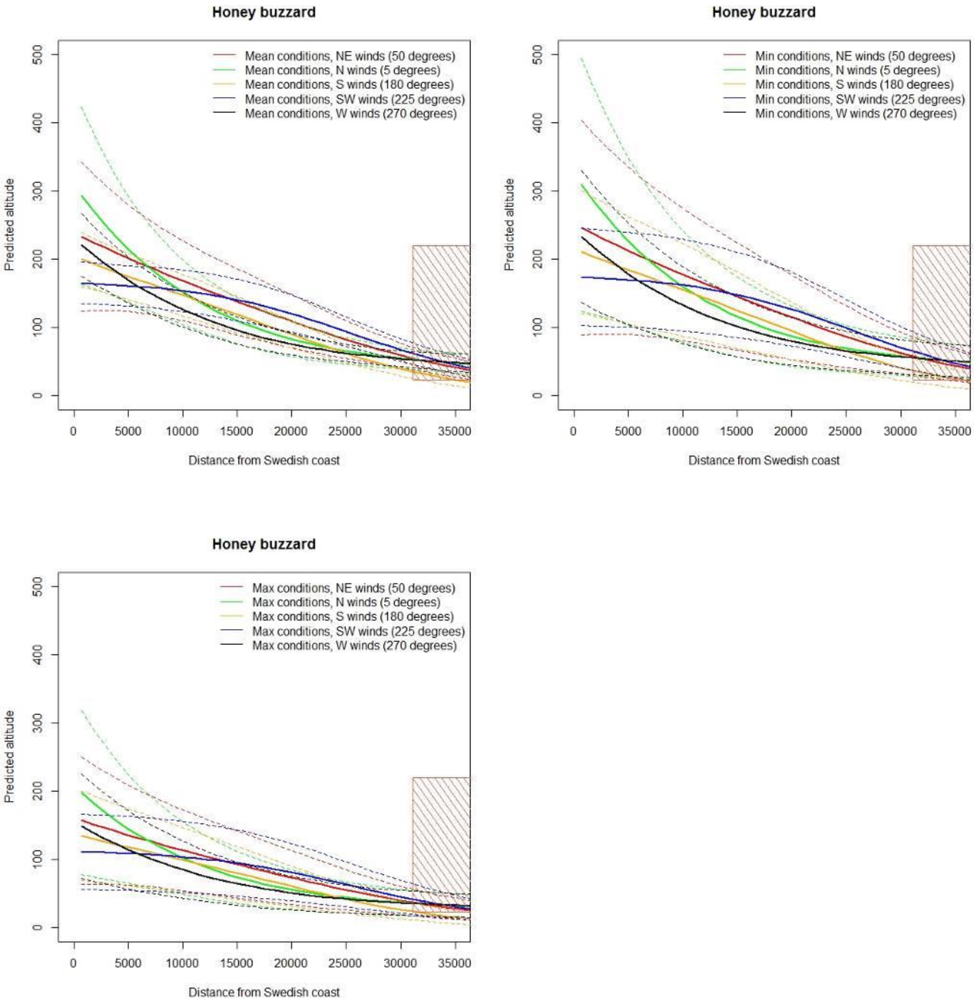
Predicted altitude in autumn in relation to distance from the coast of Sweden for the Sparrowhawk during different wind directions with all other predictor variables set to mean (upper left), minimum (upper right) or maximum (lower left) conditions during the specific wind conditions. The dashed lines indicate the model standard errors. The rectangle with shading red lines indicates the rotor swept area.



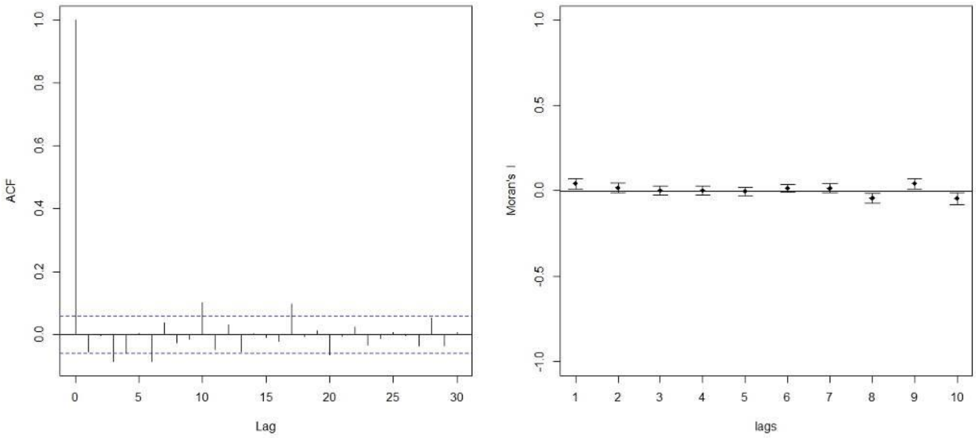
Serial (to the left) and spatial autocorrelation (to the right) in the residuals of the lme part of the GAMM for the Honey Buzzard. 1 lag =250m in correlogram (to the right) and the bars indicate the square root of the estimated Moran's I value.



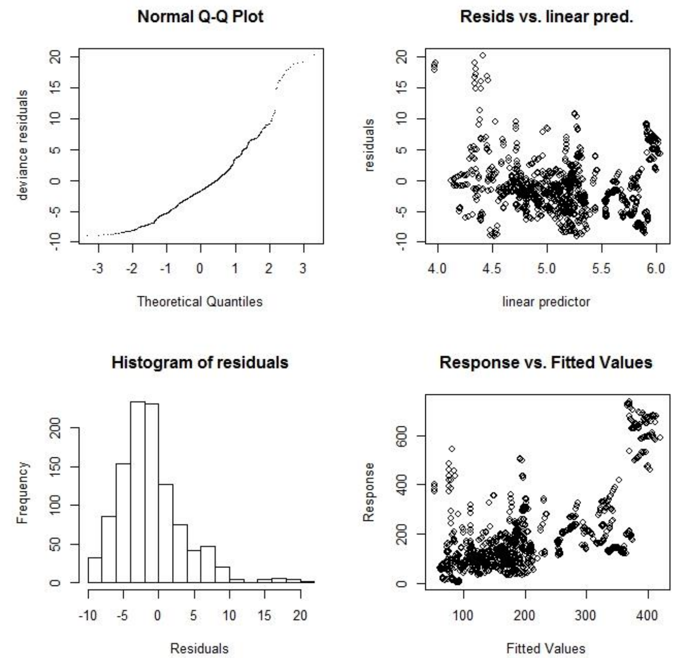
Diagnostics of the gam part of the GAMM for the Honey Buzzard. Normality of the residuals is displayed in the graphs to the left. The spread of the residuals are visualised in the upper right and the observed against predicted values in the lower right plot.



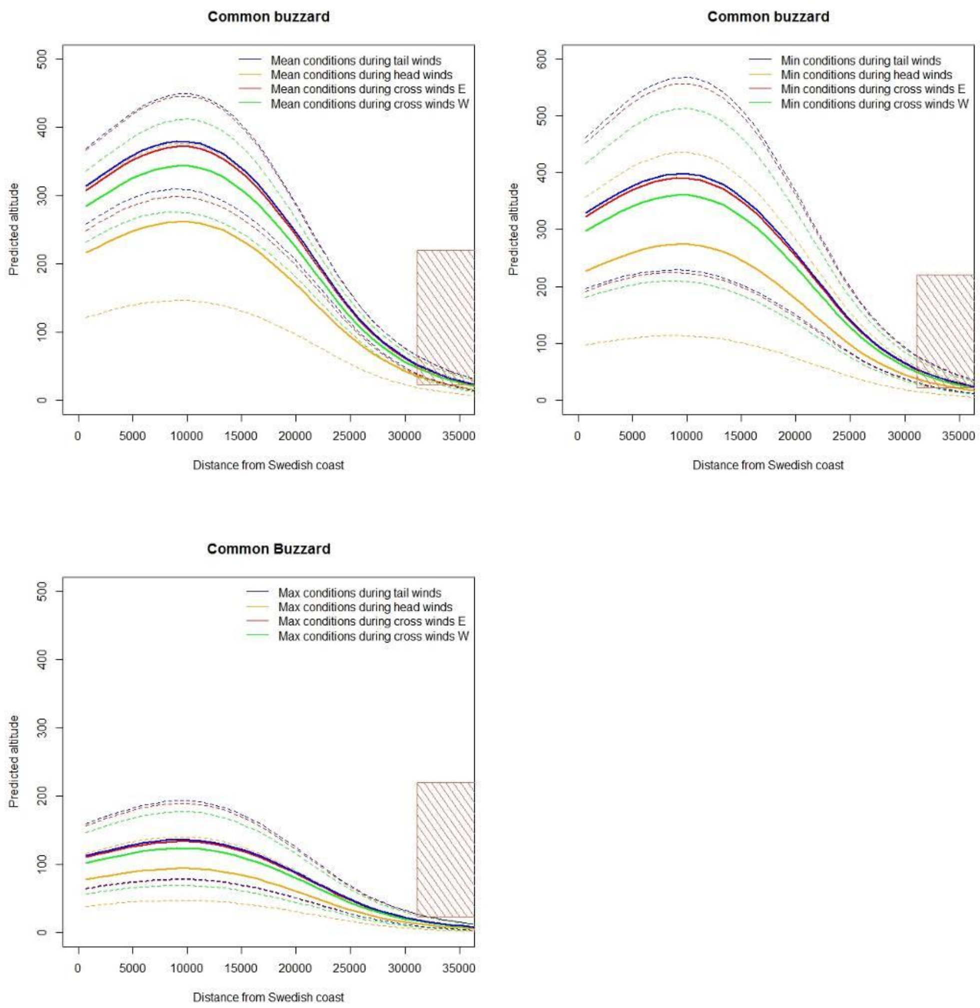
Predicted altitude in autumn in relation to distance from the coast of Sweden for the Honey Buzzard during different wind directions with all other predictor variables set to mean (upper left), mininimum (upper right) or maximum (lower left) conditions during the specific wind conditions. The dashed lines indicate the model standard errors. The rectangle with shading red lines indicates the rotor swept area.



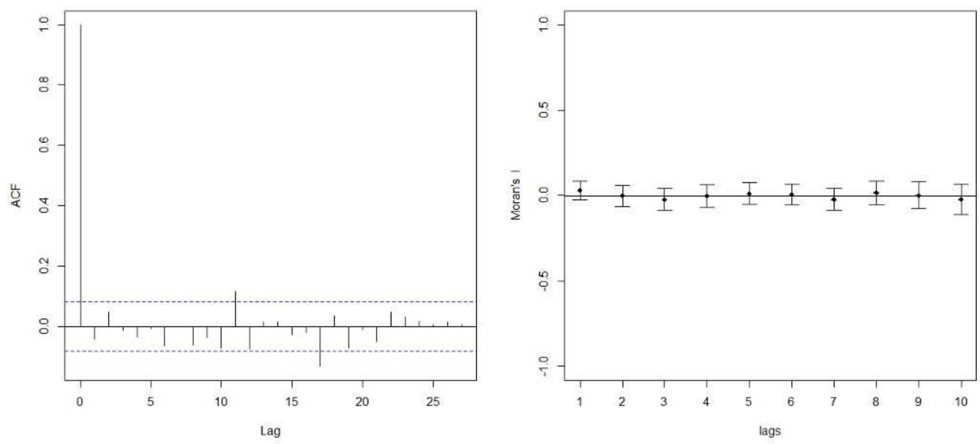
Serial (to the left) and spatial autocorrelation (to the right) in the residuals of the lme part of the GAMM for the Common Buzzard. 1 lag =250m in correlogram (to the right) and the bars indicate the square root of the estimated Moran's I value.



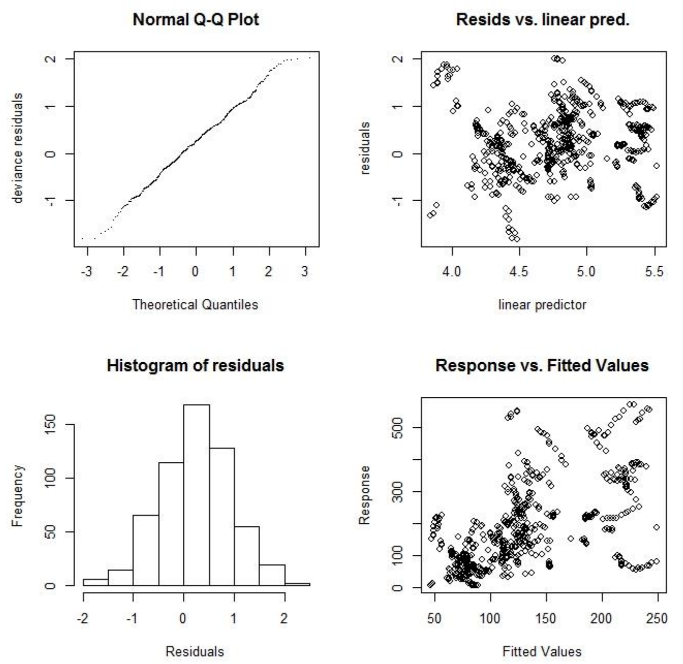
Diagnostics of the gam part of the GAMM for the Common Buzzard. Normality of the residuals is displayed in the graphs to the left. The spread of the residuals are visualised in the upper right and the observed against predicted values in the lower right plot.



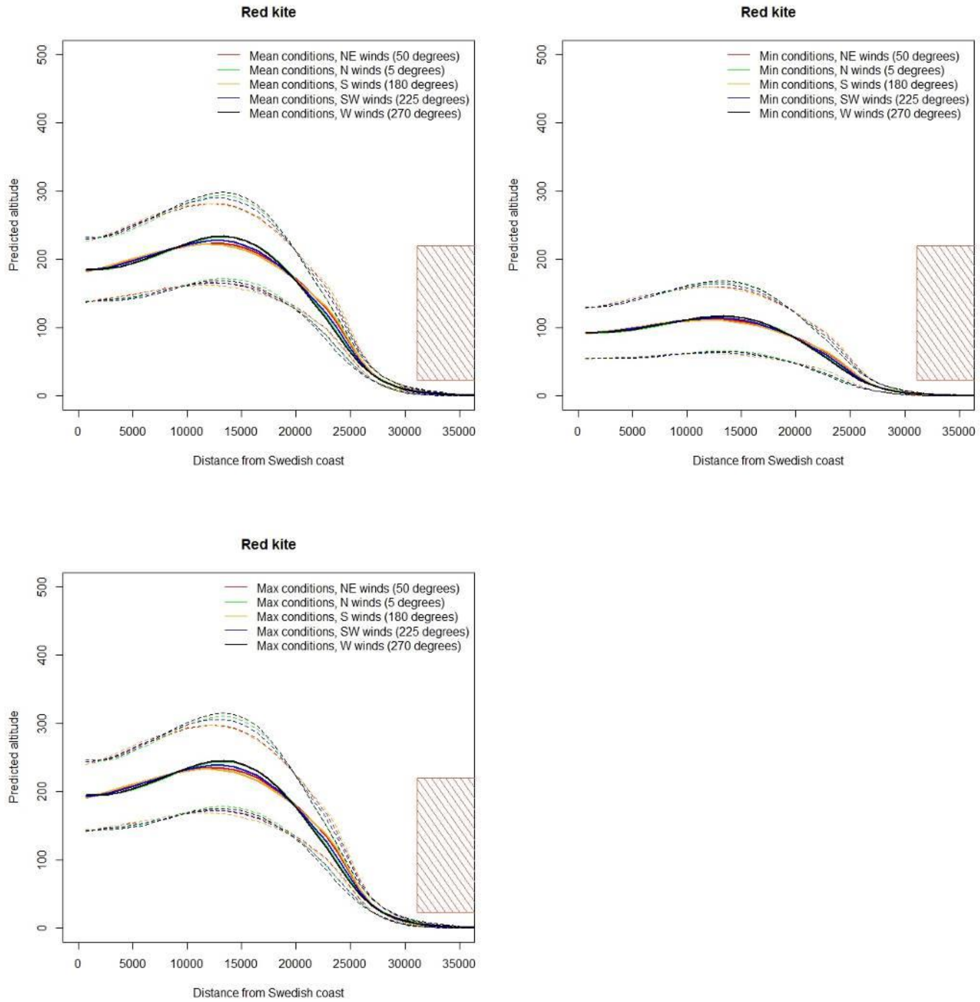
Predicted altitude in autumn in relation to distance from the coast of Sweden for the Common Buzzard during different wind directions with all other predictor variables set to mean (upper left), minimum (upper right) or maximum (lower left) conditions during the specific wind conditions. The dashed lines indicate the model standard errors. The rectangle with shading red lines indicates the rotor swept area.



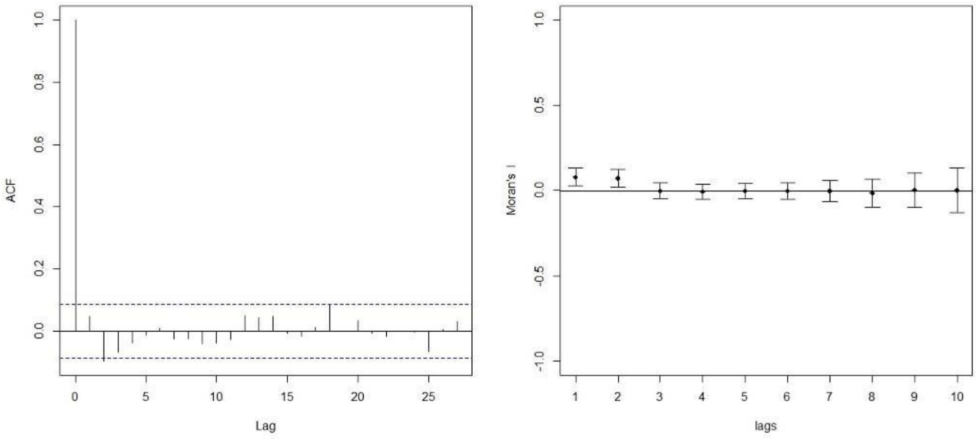
Serial (to the left) and spatial autocorrelation (to the right) in the residuals of the lme part of the GAMM for the Red Kite. 1 lag =250m in correlogram (to the right) and the bars indicate the square root of the estimated Moran's I value.



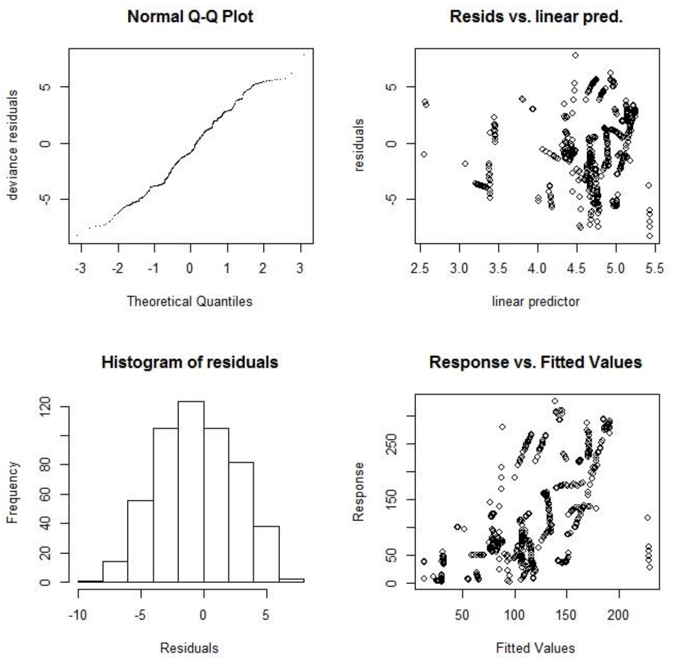
Diagnostics of the gam part of the GAMM for the Red Kite. Normality of the residuals is displayed in the graphs to the left. The spread of the residuals are visualised in the upper right and the observed against predicted values in the lower right plot.



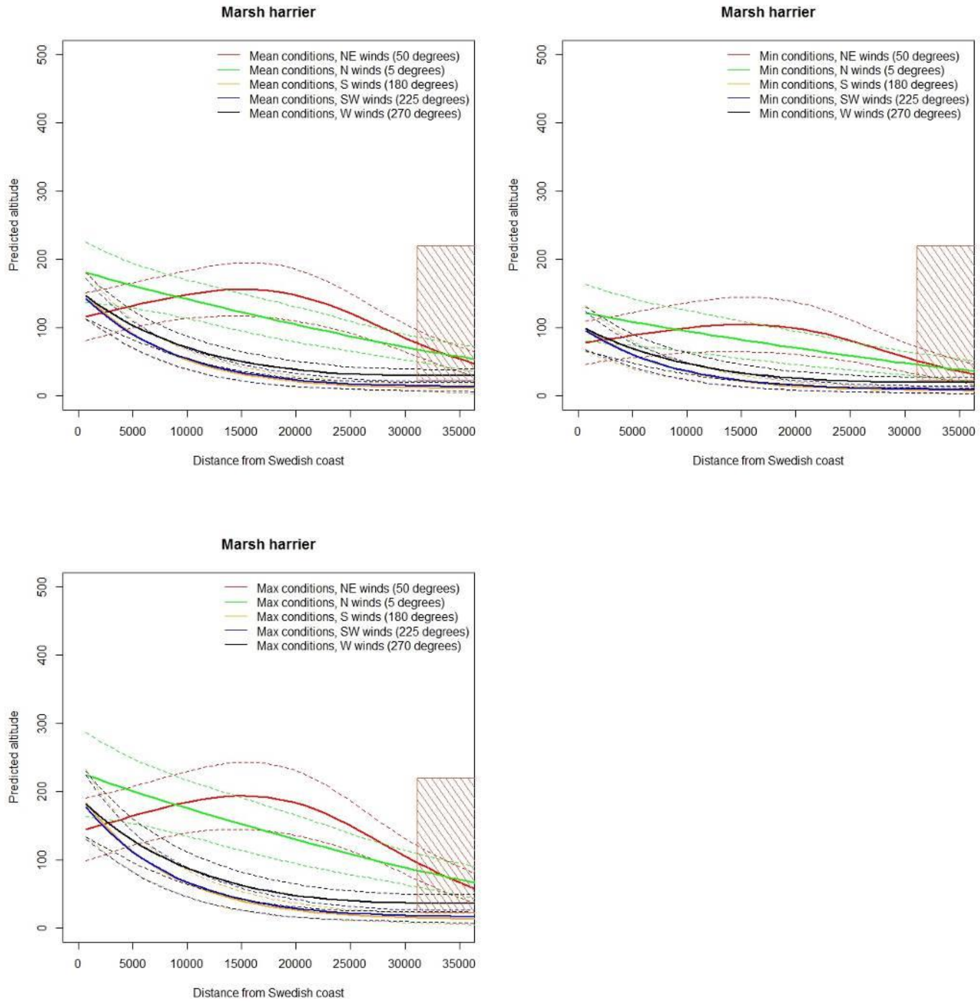
Predicted altitude in autumn in relation to distance from the coast of Sweden for the Red Kite during different wind directions with all other predictor variables set to mean (upper left), minimum (upper right) or maximum (lower left) conditions during the specific wind conditions. The dashed lines indicate the model standard errors. The rectangle with shading red lines indicates the rotor swept area.



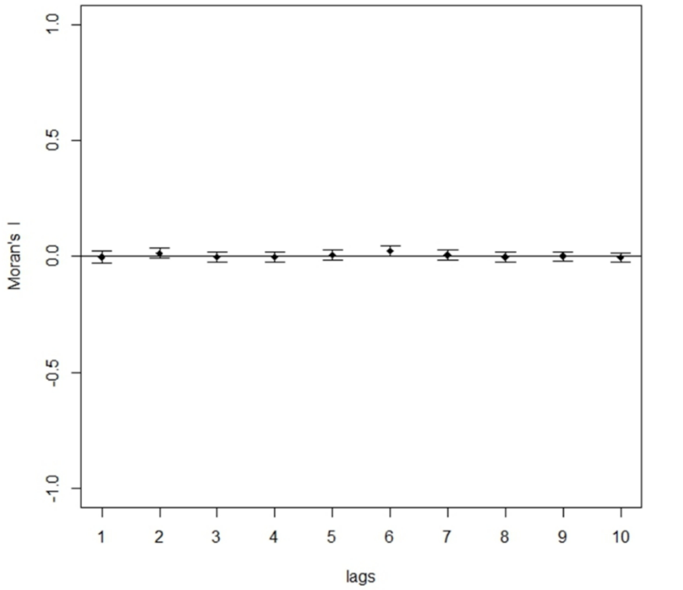
Serial (to the left) and spatial autocorrelation (to the right) in the residuals of the lme part of the GAMM for the Marsh Harrier. 1 lag =250m in correlogram (to the right) and the bars indicate the square root of the estimated Moran's I value.



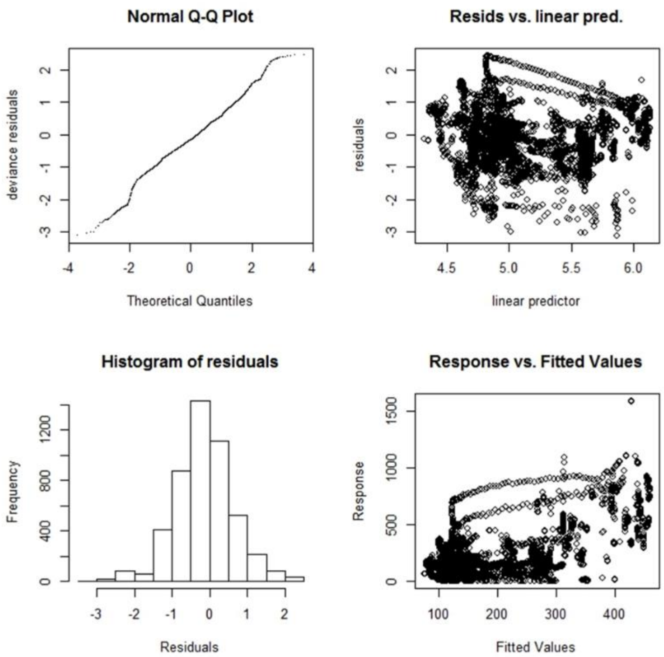
Diagnostics of the gam part of the GAMM for the Marsh Harrier. Normality of the residuals is displayed in the graphs to the left. The spread of the residuals are visualised in the upper right and the observed against predicted values in the lower right plot.



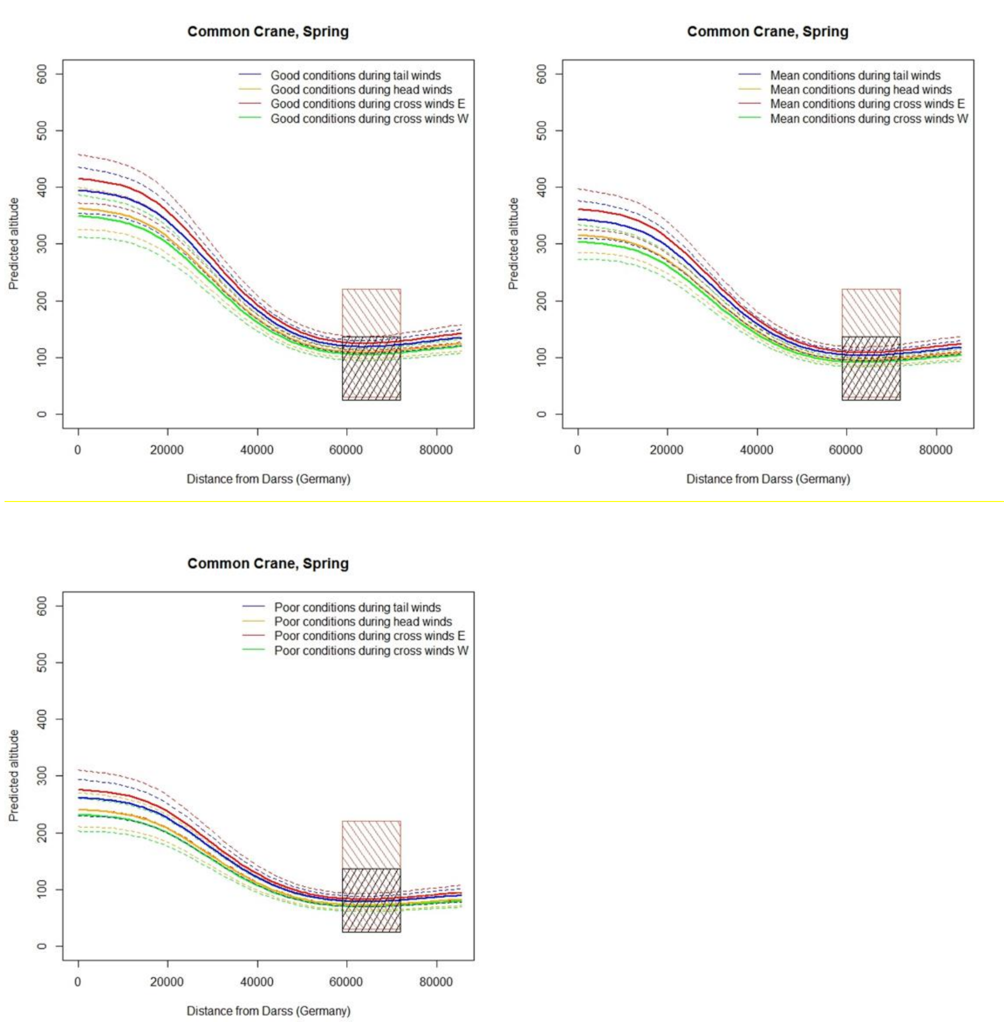
Predicted altitude in autumn in relation to distance from the coast of Sweden for the Marsh Harrier during different wind directions with all other predictor variables set to mean (upper left), minimum (upper right) or maximum (lower left) conditions during the specific wind conditions. The dashed lines indicate the model standard errors. The rectangle with shading red lines indicates the rotor swept area.



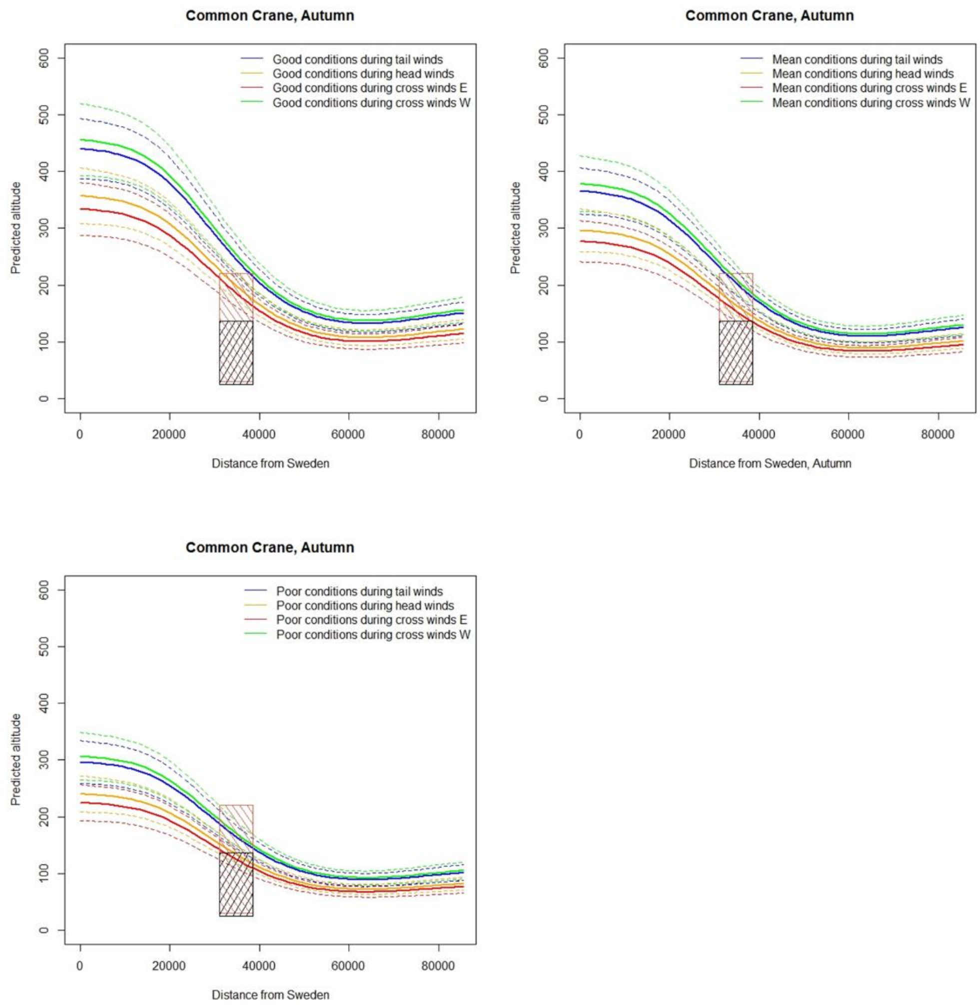
Spatial autocorrelation in the residuals of the lme part of the GAMM for the Common Crane. 1 lag =250m in correlogram (to the right) and the bars indicate the square root of the estimated Moran's I value.



Diagnostics of the gam part of the GAMM for the Common Crane. Normality of the residuals is displayed in the graphs to the left. The spread of the residuals are visualised in the upper right and the observed against predicted values in the lower right plot.



Predicted altitude in spring in relation to distance from the coast of Germany for the Common Crane during different wind directions with all other predictor variables set to mean (upper right), minimum (lower left) or maximum (upper left) conditions during the specific wind conditions. The dashed lines indicate the model standard errors. The cross-hatched rectangle indicates the rotor swept area of the 3 MW turbine, while the single-hatched red rectangle indicates the rotor swept area of the 10 MW turbine.



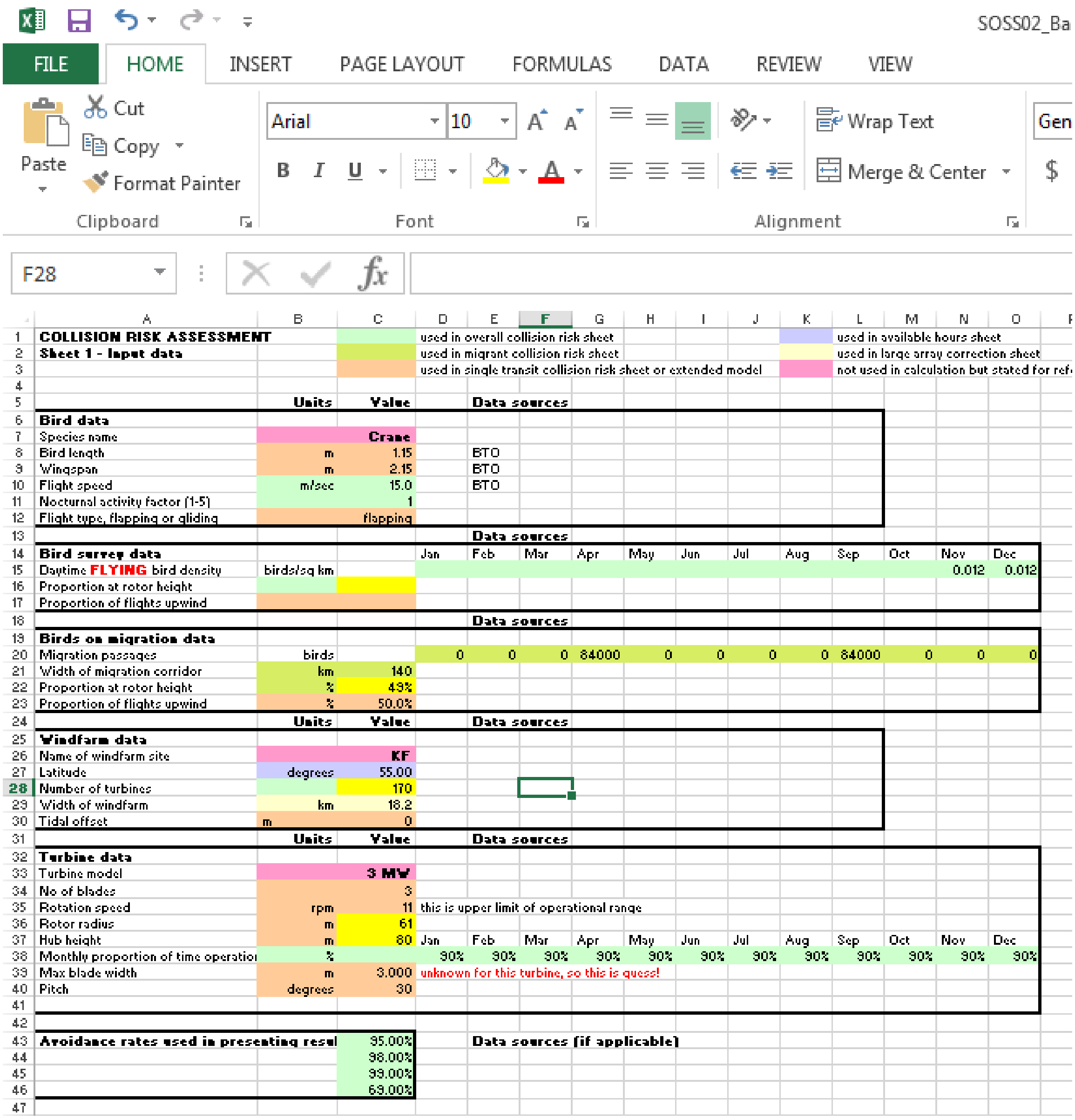
Predicted altitude in autumn in relation to distance from the coast of Sweden for the Common Crane during different wind directions with all other predictor variables set to mean (upper right), minimum (lower left) or maximum (upper left) conditions during the specific wind conditions. The dashed lines indicate the model standard errors. The cross-hatched rectangle indicates the rotor swept area of the 3 MW turbine, while the single-hatched red rectangle indicates the rotor swept area of the 10 MW turbine.

APPENDIX B – Collision risk model application

Screen shots of Band (2012) model

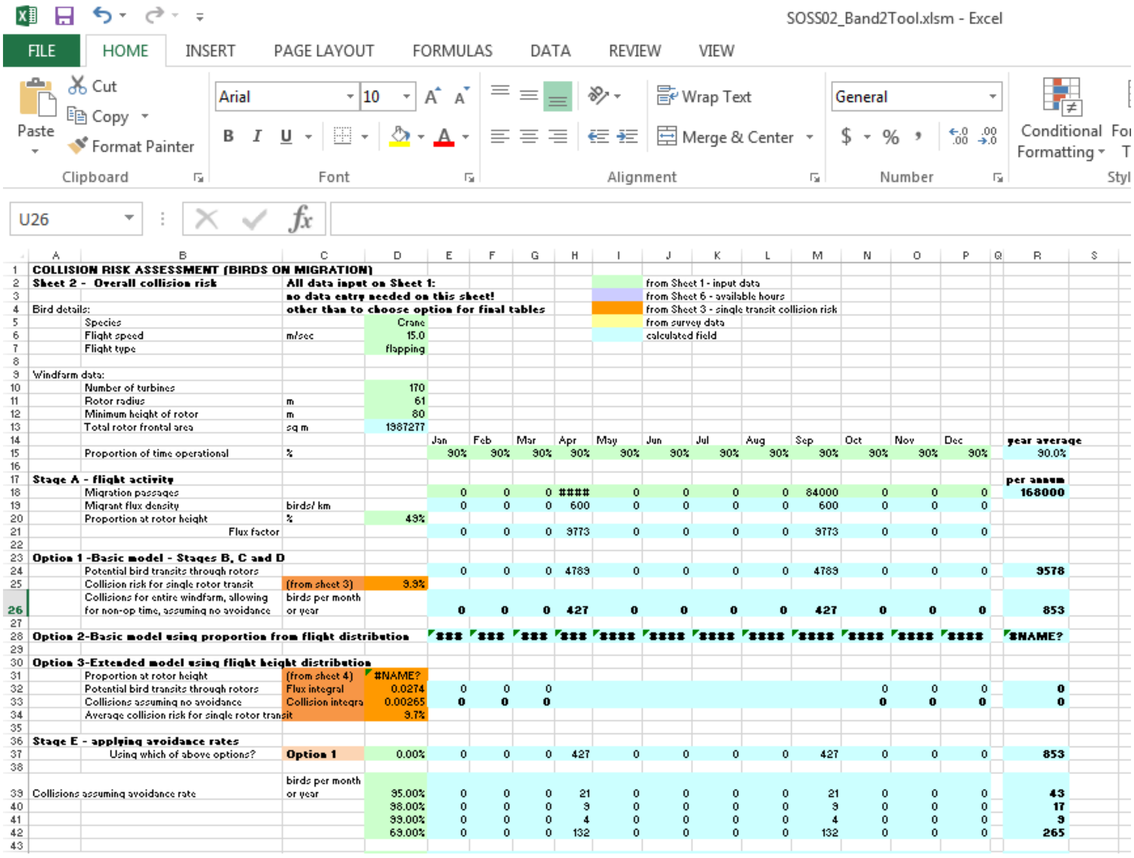
Collision risk model application (examples 3.6 MW)

Table B.1 Screen shots of Band (2012) model: data input page



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	COLLISION RISK ASSESSMENT			used in overall collision risk sheet								used in available hours sheet			
2	Sheet 1 - Input data			used in migrant collision risk sheet								used in large array correction sheet			
3				used in single transit collision risk sheet or extended model								not used in calculation but stated for ref			
4															
5		Units	Value		Data sources										
6	Bird data														
7	Species name		Crane												
8	Bird length	m	1.15		BTO										
9	Wingspan	m	2.15		BTO										
10	Flight speed	m/sec	15.0		BTO										
11	Nocturnal activity factor (1-5)		1												
12	Flight type, flapping or gliding		flapping												
13					Data sources										
14	Bird survey data			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
15	Daytime FLYING bird density	birds/sq km												0.012	0.012
16	Proportion at rotor height														
17	Proportion of flights upwind														
18					Data sources										
19	Birds on migration data														
20	Migration passages	birds		0	0	0	84000	0	0	0	0	84000	0	0	0
21	Width of migration corridor	km	140												
22	Proportion at rotor height	%	49%												
23	Proportion of flights upwind	%	50.0%												
24		Units	Value		Data sources										
25	Windfarm data														
26	Name of windfarm site		KF												
27	Latitude	degrees	55.00												
28	Number of turbines		170												
29	Width of windfarm	km	18.2												
30	Tidal offset	m	0												
31		Units	Value		Data sources										
32	Turbine data														
33	Turbine model		3 MW												
34	No of blades		3												
35	Rotation speed	rpm	11	this is upper limit of operational range											
36	Rotor radius	m	61												
37	Hub height	m	80	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
38	Monthly proportion of time operatio	%		90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
39	Max blade width	m	3.000	unknown for this turbine, so this is guess!											
40	Pitch	degrees	30												
41															
42															
43	Avoidance rates used in presenting resul		95.00%		Data sources (if applicable)										
44			98.00%												
45			99.00%												
46			69.00%												
47															

Table B.2 Screen shots of Band (2012) model: result page



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	**COLLISION RISK ASSESSMENT (BIRDS ON MIGRATION)**																	
2	**Sheet 2 - Overall collision risk**		**All data input on Sheet 1:**							from Sheet 1 - input data								
3			**no data entry needed on this sheet!**							from Sheet 6 - available hours								
4	Bird details:		**other than to choose option for final tables**							from Sheet 3 - single transit collision risk								
5		Species		Crane						from survey data								
6		Flight speed	m/sec	15.0						calculated field								
7		Flight type		flapping														
8																		
9	Windfarm data:																	
10		Number of turbines		170														
11		Rotor radius	m	61														
12		Minimum height of rotor	m	80														
13		Total rotor frontal area	sq m	1987277														
14					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		**year average**
15		Proportion of time operational	%		90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%		90.0%
16																		
17	**Stage A - flight activity**																	**per annum**
18		Migration passages			0	0	0	####	0	0	0	0	84000	0	0	0		**168000**
19		Migrant flux density	birds/ km		0	0	0	600	0	0	0	0	600	0	0	0		
20		Proportion at rotor height	%	49%														
21		Flux factor			0	0	0	9773	0	0	0	0	9773	0	0	0		
22																		
23	**Option 1 -Basic model - Stages B, C and D**																	
24		Potential bird transits through rotors			0	0	0	4789	0	0	0	0	4789	0	0	0		**9578**
25		Collision risk for single rotor transit	(from sheet 3)	9.9%														
26		Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**0**	**0**	**0**	**427**	**0**	**0**	**0**	**0**	**427**	**0**	**0**	**0**		**853**
27																		
28	**Option 2-Basic model using proportion from flight distribution**				**###**	**###**	**###**	**###**	**####**	**####**	**####**	**####**	**####**	**####**	**####**	**####**		**#NAME?**
29																		
30	**Option 3-Extended model using flight height distribution**																	
31		Proportion at rotor height	(from sheet 4)	#NAME?														
32		Potential bird transits through rotors	Flux integral	0.0274	0	0	0							0	0	0		**0**
33		Collisions assuming no avoidance	Collision integra	0.00265	**0**	**0**	**0**							**0**	**0**	**0**		**0**
34		Average collision risk for single rotor transit		9.7%														
35																		
36	**Stage E - applying avoidance rates**																	
37		Using which of above options?	**Option 1**	0.00%	0	0	0	427	0	0	0	0	427	0	0	0		**853**
38																		
39	Collisions assuming avoidance rate		birds per month or year	95.00%	0	0	0	21	0	0	0	0	21	0	0	0		**43**
40				98.00%	0	0	0	9	0	0	0	0	9	0	0	0		**17**
41				99.00%	0	0	0	4	0	0	0	0	4	0	0	0		**9**
42				69.00%	0	0	0	132	0	0	0	0	132	0	0	0		**265**
43																		