National Environmental Research Institute
Ministry of the Environment · Denmark

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Environmental Impact Assessment

NERI Report
Commisioned by Energy E2
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Data sheet

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Contents

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Summary

This report provides background information on bird interactions to the process of developing a formal Environmental Impact Assessment for the second offshore wind farm planned for Horn Rev (hereafter Horns Rev 2), situated c. 30 km west of Blåvands Huk along the Danish coast of the North Sea. Construction of Horns Rev 2 is planned to commence in April 2008, and will start operation in October 2009. The plan proposes a maximum of 95 2.3 MW wind turbines, with three larger experimental turbines, potentially up to 200 m high. At present, no final decision has been made on the precise numbers and types of wind turbines involved, but the final power rating for the wind farm may not exceed 215 MW, including the experimental machines. Similarly, a decision on the precise position of the turbines has not been taken, but at present two alternative sites (the preferred option "North" and an alternative option "South", see Fig. 1) have been proposed, each covering an area of up to 35 km^2.

The eastern part of the North Sea, and the Horns Rev area in particular, is an important wintering and migration staging area for a large number of bird species, especially waterbirds. The area is also an important migration route, especially along the coast and associated with Blåvands Huk, where both terrestrial and waterbird species congregate in large numbers along the coast during migration periods.

As a consequence of the important concentrations of migratory birds, Denmark has a special international responsibility under the Ramsar and Bonn Conventions and the European Union Directive on Wild Birds to protect and maintain avian populations and the habitats upon which they rely within its territory. Under the criteria of the Ramsar Convention, an area is recognised as being of international importance for birds 1% (or more) of the individuals of a flyway population uses a site on a regular basis at some stage in the annual cycle. Under this criterion, the area around Horns Rev and Blåvands Huk is of international importance for non-breeding divers, Eider, Common Scoter, Arctic Tern and Sandwich Tern. Other species, such as Razorbill and Guillemot occur in significant numbers for Denmark, but do not exceed the 1% threshold.

Historical observations of birds in the vicinity of Horns Rev are almost entirely restricted to the coast at Blåvands Huk. Observations of birds offshore have received much less attention and are restricted to infrequent surveys from boats or aircraft. Between 1999 and 2005, more detailed observations of avian abundance and distribution became available through the detailed surveys associated with the first Horns Rev offshore wind farm (hereafter Horns Rev 1). Unfortunately, the surveys associated with Horns Rev 1 did not completely cover the proposed development areas for the Horns Rev 2 project, so six special aerial surveys (covering an area of c. 1796 km^2) were undertaken in the winter of 2005/6 to describe the distribution and abundance of waterbirds in the vicinity of the two proposed development areas to contribute data to this report and the environmental

impact assessment process. The coastal areas off Skallingen and Fanø, that held high concentrations of Common Scoters during the Horns Rev 1 surveys, were not included in these surveys.

Results from both sets of aerials surveys confirmed that the offshore waters around Horns Rev support generally low concentrations of waterbirds. Occasionally large concentrations of marine species occur, such as divers and auks, but they show large fluctuations in number and distribution between counts, probably in response to variations in the distribution and abundance of pelagic fish which are their prey. The survey results also showed that Common Scoter have exhibited profound changes in their distribution and abundance since the late 1990s. In the earliest surveys, numbers were restricted to the coast around Skallingen and the island of Fanø, but gradually in the course of the study period, they have been registered more and more along the length of Horns Rev itself, increasingly spreading westwards along the northern side of the reef.

Based on the six aerial surveys undertaken in connection with the impact assessment, it would appear that most species use slightly less the 55 km^2 area appointed for the planned Horn Rev 2 wind farm and the alternative "South" option area (65 km^2) than the entire study area as a whole, based on analysis of survey data using Jakob's index of preference. This index of selectivity can register from -1 (complete avoidance) to +1 (complete preference). For almost all species, less than 5% of the registered birds in the survey area were observed in either Horns Rev 2 development area. Only Kittiwake (2% and 6% in the "north" and "South" areas) and Common Scoter (25% and 21% respectively) were the exceptions. Common Scoter showed a distinct preference for both of the potential wind farm areas (Jakob's indices of +0.80 and +0.74), whereas Kittiwake did not.

Common Scoter was by far the most numerous species observed during the aerial surveys, and because the species showed such preference for the potential development areas, it was subject to special analyses. Distance sampling and spatial modelling were used to generate density estimates in 500 x 500 m grids throughout the entire study area for each survey count. This showed the study area supported between 9,397 and 93,848 Common Scoter, making the area of international importance. Because there are strong reasons for suspecting that Common Scoter avoid the vicinity of wind turbines from experiences at Horns Rev 1, we estimated the hypothetical numbers of Common Scoter that would have been displaced from the areas between the two potential development areas based on these count data. This calculation assumed a linear displacement extending gradually out to 2 km from the nearest turbine, beyond which no further effect could be detected, and a possible future habituation towards the presence of the turbines was not incorporated. Based on this assumption, between 6,173 and 29,135 Common Scoter would potentially be affected within the area of the proposed Horn Rev 2 and 5,262 and 37,133 at the "South" option. These numbers exceed 16,000 birds which constitute the international importance threshold for the Western Palearctic flyway population of Common Scoter. The numbers and distribution of Common Scoter is supposed to be highly related to the presence of prey items in suitable densities and size classes. Investigations have shown that American Razor Clam is the favoured food item for Common Scoter at Horns Rev. American Razor Clam is expected to be part of the Horns Rev mollusc fauna in the future, but with high local variation in their distribution. This is expected to influence the numbers and distribution of Common Scoters in the area.

The report concentrates upon the effects of the operational phase of the Horns Rev 2 offshore wind farm, including the experimental turbines. It takes no account of the construction phase itself or of the laying of the cable to land, because these operations are considered to be of short duration in comparison the 25 year operating life of the wind farm. Construction activities are expected to be carried out during the summer, where few birds are present in the area as compared to the remaining parts of the year.

As well as presenting an assessment of the distribution and abundance of birds in the vicinity of the planned Horns Rev 2 sites, the report also considers other information about birds in the general area and reviews our knowledge of the likely effects and reactions of birds to wind turbines in general and offshore wind farms in particular.

Potential permanent effects of offshore wind farms on birds can be summarised under three main headings:
1. Physical changes to habitat
2. Avoidance effects (effective habitat loss)
3. Collision risk.

In addition, because Horns Rev 2 will be constructed within 13.9 km of the existing Horns Rev 1, the report also considers potential cumulative effects arising from the two development projects in concert.

Physical changes to habitat include 1) loss of habitat under foundations, 2) creation of novel substrates (typically hard substrates of the foundations and anti-scour protection) where invertebrate colonisation can occur and 3) creations of perches (turbine superstructures, especially railings) where birds can rest and loaf. Habitat loss amounts to less 0.1% of the total wind farm area and is therefore impossible to measure with respect to bird use. Furthermore, the predation by starfish of settling invertebrates (such as barnacles and mussels) and the lack of obvious changes in fish populations documented at Horns Rev 1, suggest that colonisation of foundations and anti-scour protection will have little or no effect on the food base available for birds at Horns Rev 2. At Horns Rev 1, the relatively few birds that have been registered loafing on turbines have been along the outer periphery of the wind farm, mostly gulls and Cormorants, and there is no reason to suppose there will be any difference at Horns Rev 2.

Based on the previous studies, only divers and Common Scoter were apparently displaced from exploiting areas between the turbines at Horns Rev 1. At Horns Rev 2, divers occurred in very small relative and absolute numbers, such that if displacement occurred at either site, it would have little effect locally. Common Scoter however occurred within both potential development areas in regular numbers that exceeded the threshold for international importance and the displacement of such number needs to be carefully considered in the environmental impact assessment.

The risk of avian collision at Horns Rev 2 could not be modelled for the most numerous species because of the absence of species specific flight trajectory data. However, given the general avoidance of turbines shown by most species at sea both at Nysted and Horns Rev 1, it is considered that the risk is reduced based on the result of the observed reactions of birds to turbines. This is confirmed by the fact that 70-85% of birds approaching Horns Rev 1 avoid entering into the wind farm, preferring to fly around the periphery. Combined radar and visual observations confirm those that do enter the park tend to fly down midway between turbine rows and seek the shortest distance to exit the park, further reducing near encounters with turbines and rotor blades. These patterns are unlikely to differ between conditions prevailing at Horns Rev 1 and 2.

The cumulative effects of the construction of two Horns Rev wind farms in close proximity have the potential of doubling the area that birds may not exploit, if the birds are disturbed by the turbines. In addition, two wind farms may potentially pose a barrier to migrating birds, if migrating birds are reluctant to pass in between the 14 km opening between the two wind farms. Depending on their precise reaction, that could cause birds to extend their migration flights (by flying around the outer edge of the parks rather than pass through the 14 km wide corridor between them) or increase the risk of collision by forcing the birds to make turns before eventually making passages through the parks. In the case of the former, it is considered that the extra energy expenditure associated with extending migration routes by such a detour would be relatively minor and of little consequence to the long distance migrants that use this migration route. For species that remain in the area for longer periods of staging or wintering, and which pass daily through the area between feeding and roosting areas, the enhanced energy expenditure could be substantial. However, for the most relevant species, the Gannet and Common Scoter, the experiences from Horns Rev 1 are that these species in general move along the periphery of the wind farms even if they are reticent to fly between the turbines, so this effect is unlikely to occur.

It is predicted that the risk of collisions with the larger experimental wind turbines will be marginally greater than for conventional turbines, because of the larger reach of the rotors, but this may be offset to some extent by the greater distance between them. A full appraisal will require more technical detail. The construction of three such experimental turbines is not considered to add significantly to the overall (and generally low) risk of collision at Horns Rev 2, especially as the majority of birds will react to the visual stimulus of an extensive wind farm at great distance, regardless of the size of individual turbines. Nevertheless, the precise positioning of the three experimental wind turbines ought to be considered carefully in this respect to avoid locating these in situations which could enhance collision risk.

Dansk resume

Denne rapport udgør den tekniske baggrundsrapport for den ornitologiske VVM-vurdering for den anden havbaserede vindmøllepark opstillet på Horns Rev, herefter benævnt Horns Rev 2 vindmøllepark, c. 30 km vest for Blåvands Huk i den danske del af Nordsøen. Anlæggelse af Horns Rev 2 vindmøllepark er planlagt til at begynde i april 2008, og parken forventes at sættes i drift i oktober 2009. Parken vil bestå af maximalt 95 vindmøller, hver på 2,3 MW, samt tre større forsøgsmøller med en maksimal højde på 200 m. På nuværende tidspunkt er de endelige mølletyper og antal ikke kendt, men parken må samlet set ikke overskride en kapacitet på 215 MW inklusiv de tre forsøgsmøller. Den endelige placering af parken afventer en afgørelse mellem to udvalgte områder. Der arbejdes med et foretrukket område benævnt "Nord", og et alternativt område benævnt "Syd" (se Fig. 1). Parken vil samlet, og uanset antallet af møller og placering, dække et område på 35 km^2.

Den østlige del af Nordsøen og Horns Rev området udgør et væsentligt raste- og overvintringsområde for et stort antal vandfugle. Desuden forekommer der et markant træk af fugle gennem Horns Rev området, særligt nær kysten og ved Blåvands Huk, hvor både havfugle og terrestriske fuglearter koncentreres langs kystlinien under trækket.

Som konsekvens af store fugleforekomster i de danske farvande har Danmark forpligtigelse til, gennem både Ramsar og Bonn konventionerne og EF Fuglebeskyttelsesdirektivet, at beskytte og bevare disse bestande. I henhold til Ramsar konventionen er et område af international betydning for en fugleart hvis 1% eller mere af bestanden forekommer på et givent tidspunkt af året. Ifølge dette kriterium er området ved Horns Rev og Blåvands Huk af international betydning for lommer, Ederfugl, Sortand, Fjordterne og Splitterne. Andre arter, f.eks. Lomvie og Alk, forekommer i betydelige antal, men udgør mindre end 1% af bestandene.

Tidligere registreringer af fugle i Horns Rev området er næsten udelukkende foretaget fra kysten ved Blåvands Huk. Tællinger af fugleforekomsterne længere til havs er i mindre udstrækning gennemført fra flyvemaskine og fra båd. Et detaljeret kendskab til fugleforekomster og udbredelse i selve Horns Rev området er senest opnået gennem undersøgelser i relation til opførelsen af den første møllepark på Horns Rev (Horns Rev 1) udført i perioden 1999 til 2005. Undersøgelsesområdet omkring Horns Rev 1 har dog ikke fuldt dækket området omkring Horns Rev 2 vindmøllepark. Som følge heraf blev der i vinteren 2005/06 gennemført seks supplerende flytællinger af fugleforekomsterne i et område inkluderende de to områder udpeget til Horns Rev 2 vindmølleparken. Dette undersøgte område dækker et område på ca. 1.796 km^2. Undersøgelsesområdet for Horns Rev 2 mølleparken omfattede ikke de lavvandede områder vest for Skallingen og Fanø, som under optællinger i forbindelse med Horns Rev 1 mølleparken havde store forekomster af Sortænder. Resultaterne af disse tællinger indgår som baggrund for vurderingen af potentielle effekter af opførelsen af Horns Rev 2 vindmøllepark.

Undersøgelser af forekomsten af fugle i farvandet omkring Horns Rev blev gennemført i forbindelse med etableringen af Horns Rev 1 vindmølleparken fra 1999 til 2005. Resultater fra disse undersøgelser viste, at Horns Rev generelt havde lave koncentrationer af fugle. Lejlighedsvis kunne høje koncentrationer af marine arter som alkefugle eller lommer forekomme, men stærkt fluktuerende i både antal og fordeling imellem optællinger. Resultaterne fra disse undersøgelser viste desuden at Sortand i løbet af undersøgelsesperioden udviste et markant skift i fordelingsmønster, hvor arten i de tidlige år næsten udelukkende forekom langs kysterne af Skallingen og Fanø, men gradvist i løbet af undersøgelsesperioden blev registreret mere og mere hyppigt på selve Horns Rev, og gradvist bevægede sig længere og længere mod vest langs den nordlige side af revet.

Baseret på de seks optællinger af fugle, foretaget i forbindelse med denne VVM-redegørelse, kunne det dokumenteres at de fleste arter anvendte det udpegede område på 55 km^2 for den planlagte Horns Rev 2 møllepark og det sydlige, alternative område på 65 km^2 i mindre grad end de udnyttede det generelle undersøgelsesområde. Dette forhold blev belyst ved beregning af et Jakobs indeks, et selektivitetsindeks gående fra -1 til +1, hvor -1 beskriver en situation hvor en given art ikke registreres i mølleparkområdet, og hvor +1 angiver at alle observationer af en given art blev foretaget i mølleparkområdet.

Generelt blev mindre end 5% af de registrerede fugle observeret indenfor Horns Rev 2 mølleparkområdet (nord) og den alternative, sydlige placering af parken. Undtaget herfra er Sortand og Ride, hvor henholdsvis 25 og 2% blev observeret i mølleparkområdet, og 21 og 6% blev observeret i området for den alternative placering. Sortand havde en høj præference for de to forslag til mølleparkplacering, med selektivitets indeks på henholdsvis +0.80 og +0.74, mens de tilsvarende værdier for Ride var -0.22 og +0.20 for de to placeringer.

Idet sortand er langt den talrigest forekommende art i undersøgelsesområdet, og da den samtidig har præferens for området for den planlagte Horns Rev 2 møllepark er behandlingen af denne art gjort til genstand for ekstra opmærksomhed. Fordi arten forekom så talrigt i området var det muligt at foretage beregninger af det totale antal Sortænder i undersøgelsesområdet samt disses geografiske fordeling indenfor dette, beregnet på grundlag af resultater for de enkelte optællinger. Beregningerne viste at der i området befandt sig imellem 9.397 og 93.848 Sortænder, og at området således rummer sortandeforekomster af international betydning. Ved hjælp af rummelig modellering var det muligt at beregne det potentielle antal fortrængte Sortænder ud fra den hypotetiske forudsætning at Sortænderne undlader at anvende selve mølleparkområdet og dets allernærmeste omgivelser (200-300 m) samt at effekten gradvist aftager ud til en afstand af 2 km. Der tages i beregningerne ikke højde for en eventuel fremtidig tilvænning til vindmølleparkerne. Det blev således beregnet at imellem 6.173 og 29.135 Sortænder vil blive fortrængt fra den planlagte Horns Rev 2 mølleparkplacering, mens tilsvarende imellem 5.262 og 37.133 Sortænder vil blive fortrængt fra den alternative, sydlige placering. Sortændernes antal og fordeling formodes at være relateret til forekomsten af favorable føderessourcer. En undersøgelse har vist at Sortænder på Horns Rev langt overvejende fouragerer på Amerikansk Knivmusling. Denne art forventes at være en permanent del af muslinge-faunaen på Horns Rev, men fordelingen af muslinger i de størrelsesklasser, der er favorable for sortænder, forventes at fluktuere imellem år, hvilket formodentlig vil afspejles i fordelingen og forekomsten af Sortand.

Nærværende rapport fokuserer på de potentielle effekter der er forbundet med almindelig drift af mølleparken, samt på potentielle effekter forårsaget af de tre store forsøgsmøller, som opsættes i forbindelse med Horns Rev 2 vindmøllepark. Rapporten inkluderer ikke en vurdering af påvirkning af fugle fra anlægsarbejdet og af etablering af kabelforbindelsen til land, idet disse aktiviteter forventes at være af kort varighed i forhold til den samlede forventede levetid på 25 år for hele mølleparken. Konstruktions aktiviteter forventes desuden at foregå i sommerperioden, hvor færrest fugle befinder sig i undersøgelsesområdet sammenlignet med den øvrige del af året.

Ud over de konkrete undersøgelser af fuglens antal og fordeling i og omkring det udpegede områder for Horns Rev 2 mølleparken, baseres vurderingerne i nærværende rapport på den eksisterende generelle viden om fugleforekomster og fordeling i Horns Rev området, samt på den eksisterende generelle viden om fugles reaktioner på mølleparker.

Potentielle permanente påvirkninger af fugle i perioden hvor møllerne er aktive kan opstilles under tre hovedoverskrifter:

1. Fysisk ændring af habitaten
2. Forstyrrelseseffekter som medfører at fuglene undgår møllerne, hvilket er det samme som tab af potentiel udnyttelse af et normalt tilgængeligt område
3. Kollisionsrisiko.

Som følge af at Horns Rev 2 vindmøllepark er den anden store møllepark i Horns Rev området, opsat ca. 13,9 km fra den nærmeste mølle i Horns Rev 1 mølleparken, inkluderer nærværende rapport en vurdering af en samlet effekt af de to mølleparker.

Fysisk ændring af habitaten omfatter 1) tab af bundareal hvor møllefundamenter opstilles, 2) forekomst af et nyt undervandsområde (møllefundamenter) hvor marine invertebrater kan leve, og 3) forekomst af platforme (møller) hvorpå fugle kan sidde eller hvile.

Tab af bundareal som følge af 98 møller vil sandsynligvis omfatte mindre end 0,1 % af mølleområdet og forventes ikke at medføre målbare påvirkninger. Tilsvarende forventes det ikke, at dannelse af en ny habitat som følge af erosionsbeskyttelse omkring møllefundamenterne markant vil medføre en stigning i forekomsten af invertebrater, idet prædation af søstjerner forhindrer kolonidannende muslinger og balanoider i at etablere sig. Forekomst af bentiske fisk og stimefisk omkring møllefundamenterne forventes, på baggrund af erfaringer fra Horns Rev 1 vindmølleparken, kun at tiltrække et mindre antal fiskeædende fuglearter, for eksempel Skarv og terner. Ved

Horns Rev 1 registreredes de fleste fugle inde i parken hovedsageligt i parkens yderområder, og et tilsvarende mønster blev registreret for fugle (måger og Skarv) der rastede på møllefundamenterne. Disse resultater indikerer, at en eventuel tiltrækning til møllerne af fødesøgende eller rastende fugle begrænses når møllerne i parken er aktive, hvilket tilsvarende må forventes at være gældende for Horns Rev 2 mølleparken.

På baggrund af tidligere studier er det meget markant, at lommer og Sortand ikke udnytter området mellem møllerne i Horns Rev 1 mølleparken. Ved området for Horns Rev 2 forekommer lommer kun i små relative og absolutte tal, hvilket betyder, at selv hvis lommer helt undgår at udnytte det aktuelle mølleområde efter parkens opførelse, vil det kun have en lille og lokal betydning for disse arter samlet set for hele Horns Rev området. Sortand derimod forekom indenfor begge de mulige møllepark områder regelmæssigt i antal som betyder, at forekomsten er af internationale betydning. Det vurderes derfor, at der er behov for at overveje betydningen af en omfordeling af Sortand på Horns Rev i forbindelse med den planlagte Horns Rev 2 møllepark.

Det vurderes, at risikoen for kollisioner mellem fugle og møllerne i Horns Rev 2 mølleparken ikke er stor. Denne vurdering baseres på undersøgelser fra Horns Rev 1, som viste at hovedparten (70-85 %) af de fugle som fløj i retning af mølleparken undgik at flyve ind mellem møllerne. Tilsvarende viste undersøgelserne også, at de fugle der passerede igennem parken, i langt de fleste tilfælde tilpassede passagen til at foregå ned mellem mollerækkerne, eller at de fløj ud af parkerne den kortest mulige vej. Et tilsvarende adfærdsmønster vil sandsynligvis også gælde for Horns Rev 2 mølleparken, idet der ikke kan forventes en forskel i forekomsten af fuglearter mellem denne møllepark og Horns Rev 1 mølleparken.

En effekt af to mølleparker på Horns Rev vil potentielt fordoble det område, som fuglene ikke kan benytte hvis de forstyrres af møllerne. Dertil kommer, at to mølleparker potentielt vil udgøre en barriere for trækkende fugle i området, hvis fuglene afholder sig fra at flyve igennem den ca. 14 km åbning der er mellem parkerne. Afhængig af fuglenes reaktioner vil en barriereeffekt kunne betyde 1) en øget flyvelængde (hvis fuglene skal flyve udenom begge parker) eller 2) en øget kollisionsrisiko (hvis fuglene flyver en eller flere gange rundt i området før de evt. passerer igennem mølleparkerne). Det vurderes at for fugle der trækker gennem området en eller to gange om året, vil energiforbruget forbundet med at flyve udenom mølleparkerne ikke være kritisk, da den ekstra tilbagelagte afstand er meget lille i forhold til den samlede længde af fuglenes trækruter. For arter der opholder sig i området gennem længere perioder og som dagligt må passere udenom mølleparkerne ved bevægelser mellem fourageringsog rasteområder, vil det ekstra energiforbrug være større. Det vurderes dog, at for relevante arter, primært Sortand og Sule, vil effekten af to mølleparker være minimal, idet begge arter er registreret i relativt store antal tæt på den eksisterende møllepark ved Horns Rev 1.

Det vurderes at risikoen for kollisioner mellem fugle og møller vil stige med møllestørrelsen, på grund af en større afstand mellem enkelte møller og et større vingespan. Opstilling af tre store forsøgsmøller ved Horns Rev 2 vurderes dog ikke at medføre en aktuel større kollisionsrisiko, idet fuglene i området sandsynligvis vil reagere på det store antal mindre møller og undvige mølleparken og ikke specifikt reagere på de tre store møller. Placeringen af de tre forsøgsmøller i forhold til selve mølleparken og i forhold til fuglenes generelle trækretning gennem området bør dog overvejes, idet en uhensigtsmæssig placering potentielt kan lede trækkende fugle tættere på disse med en øget risiko for kollisioner som konsekvens.

1 Introduction

1.1 Background

Based on the recommendations in the action plan for offshore wind farms (Anonym 1997), the Danish Government requested that the major power companies start planning the construction of five large-scale offshore demonstration wind farms in Danish waters in February 1998. In June 1999, the Ministry of Environment and Energy gave outline approval to start pre-investigations in relation to projects at Horns Rev in the North Sea, in Kattegat south of Læsø, at Omø Stålgrunde north of Lolland, and at Nysted-Rødsand and Gedser Rev, both south of Lolland. These areas were all located within the zones designated in the 1997 action plan for development of offshore wind farms.

The conditions imposed in the original consents given to these demonstration projects included specific environmental impact assessments (EIAs) relating to the projects and explicitly required before-after comparisons to demonstrate any potential impacts on the environment. The consents granted to the demonstration projects thus imposed EIAs and recommendations for relevant monitoring programs, which are not standard procedures in the EIA process.

Based on the EIAs, the project at Horns Rev 1 was approved for construction in March 2001, and the project at Nysted-Rødsand in July 2001. Elsam and Eltra were contractors for the Horns Rev 1 wind farm, comprising 80 2 MW turbines, located c. 14 km offshore from Blåvands Huk on the Danish west coast. This wind farm was operational in 2002. Energy E2, DONG and E.ON Sweden and SEAS-Transmission were contractors on the Nysted-Rødsand wind farm, comprising 72 2.3 MW turbines, located c. 11 km south of Lolland. This wind farm became operational in 2003.

In June 2002, the Danish Government relaxed the requirement for the three additional demonstrations projects, and instead embarked on the process of establishing a total of 400 MW offshore wind power under “free market” conditions in Danish waters. This planned expansion was confirmed under an energy policy agreement made in March 2004.

As part of this process, a second wind farm (with a maximum 200 MW potential rating) at Horns Rev was planned and an invitation to tender for the concession for this wind farm was opened in January 2005 to all pre-qualifying companies and/or consortiums.

The Danish Energy Authority informed Energy E2 A/S in 2005, that they won the tender process. Under the tendering process, Energy E2 A/S was then obliged to carry out an EIA process to assess the potential impacts on the environment and general nature conservation interests in the area. Energy E2 contracted, after a tending process, the Danish National Environmental Research Institute, Department of Wildlife Ecology and Biodiversity, to produce this technical report on bird issues concerning the assessment of expected impacts resulting from the presence of this second wind farm at Horns Rev, which would feed into the general EIA report.

1.2 The Horns Rev 2 wind farm project

Construction of a second offshore wind farm at Horns Rev – hereafter referred to as Horns Rev 2 – will take place approximately 30 km from the nearest point of land, Blåvands Huk, and c. 14 km from the nearest turbine in the existing Horns Rev 1 wind farm. The Horns Rev 2 wind farm should be able to generate a maximum of 200 MW, and will consist of a maximum of 95 2.3 MW turbines. In addition, three experimental 5 MW turbines of up to 200 m height may be set up. The final type and size of the ordinary turbines have not yet been decided, so a decision may result in fewer, larger turbines. As the total maximum effective power output may not exceed 215 MW, the output from the conventional turbines may have to be capped at 200 MW if the experimental turbines are set up. However, irrespective of turbine size, the wind farm area will cover 35 km^2.

The precise location of the wind farm is not fully decided, and presently there exists two possible alternative locations (Fig. 1), both contained within the designated area of 110 km^2 selected for potential development. The preferred wind farm, site is referred to as Alternative 1, covers an area of 55 km^2 within which the wind farm will be placed, whereas the alternative site, covering 65 km^2, is referred to as Alternative 2. Pending a decision on specific location, the spatial formation of the turbines is not known. Both of the two potential areas are characterized by shallow waters of 4-14 m depth, and the average wave height which varies between 0.6 m and 1.8 m, generally lowest during summer periods.

Under the present proposals initial construction activities in the area will start in April 2008, when the turbine foundations will be situated on the seabed and scour-protection will be added. During the summer of 2009, the wind turbines will be placed on the foundations and the wind farm is planned to be operational in October 2009.

1.3 The study area and general occurrence of birds

The Horns Rev 2 offshore wind farm will be located on the shallow northern slopes of the western end of the reef, which extends from the coastal area off Blåvands Huk to a point c. 30 km west. The reef can be characterised, geomorphologically, as a terminal moraine ridge, consisting of relatively well-sorted sediments of gravel and sand (Danish Hydraulic Institute 1999). The area is subject to lunar tidal cycle, with normal averages of 1.6-1.8 m between high and low tides. The tidal oscillation creates a strong current switching between northward and southward directions.

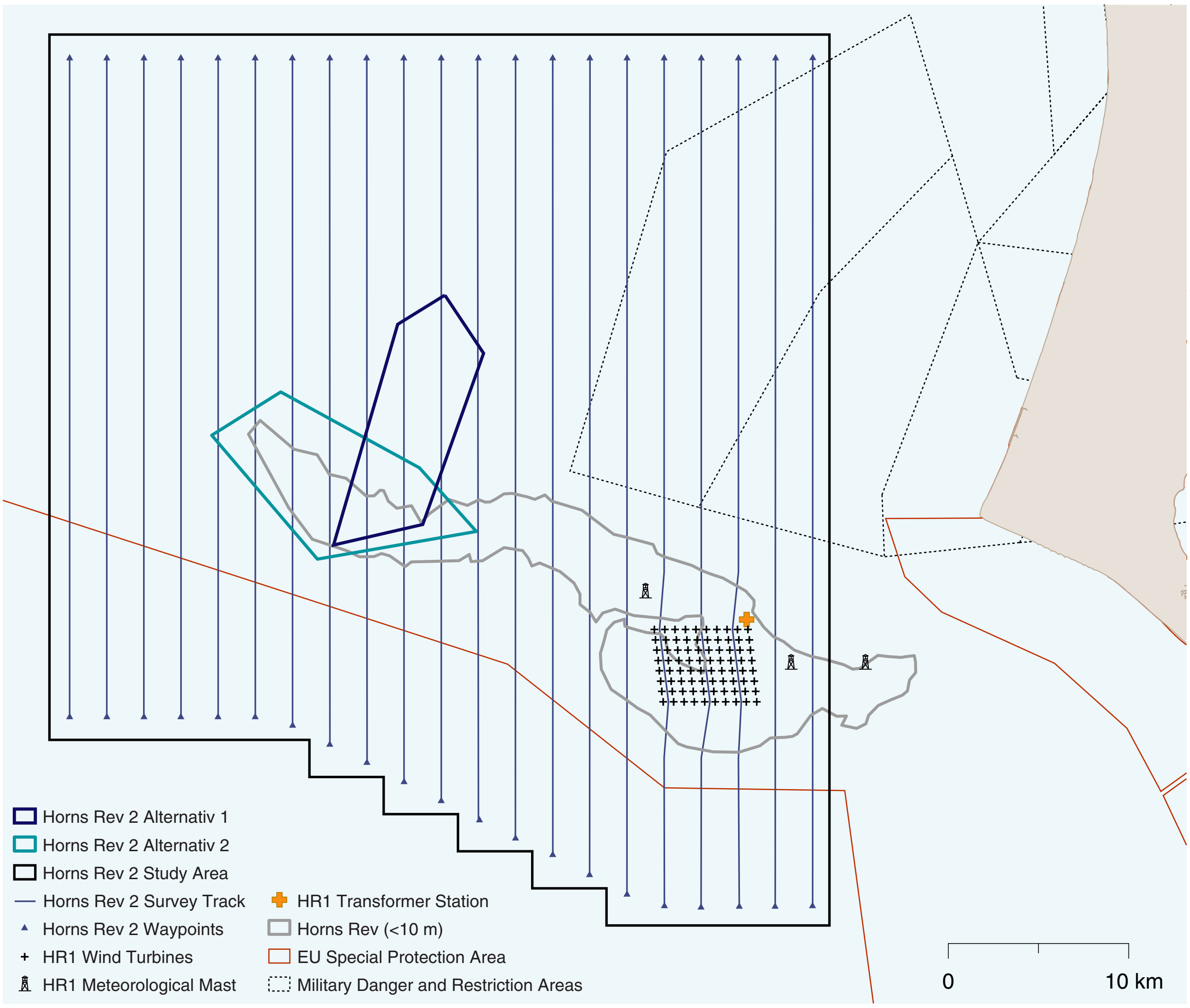

Figure 1. The Horns Rev 2 study area, showing the total survey area and survey transect net. The proposed Horns Rev 2 wind farm site (Alternative 1) and the alternative site are indicated. The Horns Rev 1 wind turbines, transformer station and meteorological masts are shown. Also shown are EU Special Protection areas and military restriction and danger areas.

The general area of Horns Rev and the planned wind farm area are situated outside any restriction or conservation area of either national or international importance. The adjacent coastal zone south of Blåvands Huk falls within the northern part of International Protection Area no. 89, which also is designated as a Special protection Area (SPA) under EC Birds Directive (area no. 57), a Special Area of Conservation (SAC) under the EC Habitats Directive (area no. 78), and a wetland of international importance under the Ramsar Convention (area no. 27) based on a long list of both breeding and staging/migrating species. In 2004, an area south of the Horns Rev has been designated as a SPA under the EC Bird Directive (area no. 113) (Fig. 1), due to the occurrence of Red- and Black-throated Diver *Gavia arctica/G. stellata* and Little Gull *Larus minutus*.

Under criteria agreed by the Ramsar convention, an area is considered of international importance to a species if 1% (or more) of its flyway population is present regularly at some time in the annual cycle (Prater 1981), the area around Horns Rev is of international importance to Red- and Black-throated Diver and to Red-necked Grebe

Podiceps grisegena (Laursen et al. 1997). More recent surveys in the area confirm its importance for divers, whereas Red-necked Grebe seems to occur in lower numbers than during previous surveys (cf. Petersen et al. in print). During the recent study at Horns Rev 1 wind farm and during the base-line surveys performed in relation to the present environmental impact assessment on birds, a very high number of Common Scoter *Melanitta nigra* has been recorded in the Horns Rev 1 survey area, accounting for as much as 24% of the Western Palearctic flyway population. Of the other bird species that occur in Horns Rev area, Little Gull, Guillemot *Uria aalge* and Razorbill *Alca torda* are all listed on the Danish red list (Stoltze & Pihl 1998a), which includes breeding species that are uncommon or immediately threatened. Of species on the Danish amber list (Stoltze & Pihl 1998b), listing non-breeding species that are potentially threatened, Red-throated Diver, Eider *Somateria mollissima*, Common Scoter, Guillemot and Razorbill occur at Horns Rev.

Systematic bird observations from the coast of Blåvands Huk since 1963 have documented substantial bird migration in the area of Horns Rev. Extremely large numbers may pass this area during migration, especially during autumn, when up to 6,000 divers, 4,000 gannets, 400-500 Cormorants, 6,000 dabbling ducks, 30,000 Eiders, 40,000-60,000 Common Scoters, 8,000 Oystercatcher 3,500 Knot, 1,400-1,500 skuas, up to 1,500 auks, 15,000 terns and up to 25,000 gulls are observed to pass in a single day (Kjær 2000, Jakobsen in print). In addition to bird migration over the sea and along the shoreline, species preferentially migrating over land also pass the Blåvands Huk area in large numbers, i.e., raptors and passerine bird species, of which some continue their migration over the North Sea. At the location of the planned Horns Rev 2 wind farm, c. 30 km from the coast, a reduced number of bird species may be expected to occur regularly, whereas higher numbers of pelagic species may be present, i.e., Divers *Gavia sp.* and Fulmars *Fulmarus glacialis*.

1.4 Scope of the present study

In order to perform a proper impact assessment of the planned Horns Rev 2 offshore wind farm on birds, a basic knowledge of bird occurrence, i.e., the numbers and distribution of staging and migrating birds in the area is needed. In the last six years, our knowledge of bird occurrence in the offshore area at Horns Rev has greatly improved, basically as a result of detailed mapping of birds carried out in relation to the studies of the Horns Rev 1 wind farm. However, even though the general study area used to describe bird abundance and distribution for the Horns Rev 1 wind farm reached 20 km west of that turbine area, these surveys did not fully cover the area around the planned sites for the Horns Rev 2 wind farm to the level required to undertake an adequate impact assessment, based on the occurrence and distributions of birds at this site. Thus, the existing data on bird distribution at the Horns Rev 2 wind farm site were not sufficient to form a basis for a full impact assessment of the establishment of the wind farm. Consequently, it was necessary to carry out new surveys of birds around the planned wind farm sites, in order to supplement the existing knowledge.

This report provides an impact assessment analysis for those staging and migrating birds that exploit and pass through the Horns Rev 2 wind farm area and its immediate surroundings. Specifically, the scope of the present report was to:

1. review the existing literature with the aim of presenting information about the occurrence, abundance and distribution of birds in the Horns Rev-Blåvands Huk area in order to document the importance of this area to specific bird species,

2. review the existing literature with the aim of presenting information about species specific avoidance, attraction and general behaviour of birds in relation to offshore wind farms and turbines in general, and to

3. monitor the occurrence and distribution of birds within and around the construction area of the Horns Rev 2 wind farm, to provide a basic knowledge of species occurrence and abundance in the wind farm site based on which potential impacts could be assessed.

Given that construction of the Horns Rev 2 offshore wind farm will take place relatively close to the existing Horns Rev 1 wind farm, the present impact assessment was also obliged to address the aspect of cumulative effects from the presence of two such large offshore constructions, specifically the potential barrier effect that these wind farms may present to birds during north- and southbound migration and/or birds making local daily movements in their vicinity.

The list of bird species recorded in the Blåvands Huk and Horns Rev area is long, but not all are relevant in relation to the assessments of impacts from offshore wind farms. Obviously, most of the species associated with terrestrial habitats and which only occasionally occur at Horns Rev, will not be subject to impacts from the wind farm. This is especially the case when considering impacts at the population level, which result from, for example, reduced foraging habitat or increased mortality from collisions with turbines. Species associated with offshore habitats are more susceptible to disturbance and more likely to be involved with collisions with wind farms, but even among these, it is likely that the responses and susceptibility to effects are highly species- (and potentially site-) specific. Species also show differential sensitivity to potential impacts from wind farms, based on their reproductive and mortality rates: small species are generally characterised by high annual mortality rates – in some cases more than 50% - but high reproductive output. Other (mainly large) species have low annual mortality – in some cases c. 10% - but low reproductive output. Thus, if for example 1% of the birds flying through a wind farm are killed by collision, mortality will increase by 2% for a species with an annual survival of 50%, but 10% for a species with an annual survival of 90%. Consequently, the highest sensitivity will therefore be among the larger species, e.g., waterfowl and birds of prey.

For the above reasons, the impact assessments in relation to birds occurring at Horns Rev will focus on those species that occur in substantial numbers and which are characteristically long-lived and with low reproduction values. For species at Horns Rev, these include divers, Gannet, Cormorants, Common Scoters, gulls, terns and auks.

2 Methods used to monitor bird abundance and distribution

2.1 Selection of study area

The study area was designed to cover the area of the proposed Horns Rev 2 wind farm site and the alternative position, as well as an area big enough to embrace impact area as well as reference area. More than half the study area for this EIA project is common with the study area for the Horns Rev 1 wind farm study site. The present study area also covers the area of the Horns Rev 1 wind farm and its immediate vicinity.

2.2 Aerial surveys

The surveys were conducted from a high winged, twin-engined Partenavia P-68 Observer, designed for general reconnaissance purposes, flying at an altitude of 76 m (250 feet) and with a cruising speed of approximately 185 km/t (100 knots).

The surveys were conducted along pre-defined transect lines. Coordinates of transect end-points were entered into the GPS of the aircraft for navigation. A total of 21 transect lines, with a total track length of 847 km was established as parallel, north-south oriented lines at two km intervals. Approximately 500 km of these transect lines overlap with the transect lines used for similar surveys of birds around the Horns Rev 1 wind farm. In the area common to the two surveys, the position of the track lines was identical in the Horns Rev 1 and Horns Rev 2 studies. The Horns Rev 2 study area was extended 12 km to the west and 14 km to the north of the Horns Rev 1 study site. The Horns Rev 2 study site covers the Horns Rev 1 wind farm and its immediate surroundings, but not including the coastal areas off Skallingen and Fanø (see Fig. 1).

During the surveys, two observers covered each side of the aircraft. Only experienced observers familiar with species identification were used. All observations were continuously recorded on dictaphones, giving information on species, number, behaviour, transect band and time. The behaviour of the observed birds included the activities: sitting (on the water), diving, flushing or flying.

Observations were related to transect bands, which were determined by using an inclinometer (predetermined angles of 10º and 25º below the horizontal measured abeam flight direction), and thus included three bands on each side of the aircraft. Beneath the aircraft, a band of 44 m on each side of the flight track could not be observed. Transect widths during the aerial surveys are shown in Fig. 2.

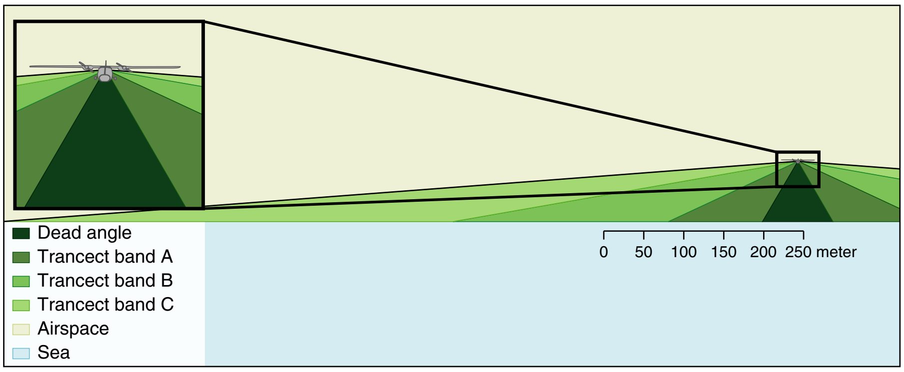

Figure 2. Transect width sketch .

During the aerial surveys a computer logged flight track data from a differential GPS at five second intervals. Each record contained longitude, latitude, altitude and time. Accuracy of GPS longitude and latitude was normally considered to be within 2 m. In the very rare situations where the GPS failed during track-logging, positions of each bird observation were calculated from the known time of passage at the way points that were used for navigation and from the cruising speed of the aircraft. In these cases the spatial accuracy of the observation data is somewhat reduced.

The majority of observations were considered to be accurate to within four seconds. With a flight speed of 185 km/h the positional accuracy on the longitudinal axis was within 206 m. In a few circumstances with high bird densities, grouping of observations in periods of up to 10 seconds may have occurred, leading to an accuracy of observation positioning of up to 515 m.

As the survey results are highly sensitive to weather conditions, surveys were not carried out when wind speed exceeded 6 m/s, because detectability of birds on the sea surface was severely reduced. Low visibility or glare also reduced detectability. In cases of severe glare, observations from one side of the aircraft were temporarily discontinued. Military activity prevented full coverage of the northeastern part of the study area on some surveys (cf. Fig. 1).

2.2.1 Species identification

It was known in advance that several pairs of birds or groups of bird species closely resembling each other occur in the study area. These comprise Red- and Black-throated Diver, Guillemot and Razorbill, Arctic *Stercorarius parasiticus*, Pomarine *S. pomarinus* and Long-tailed Skua *S. longicaudus*, and Arctic *Sterna pardisaea* and Common Tern *S. hirundo*. All of these species can only be discriminated at close range and under good visual conditions, and generally the knowledge of the species composition of these groups can only be considered approximate.

With respect to the problem in question, however, there is no *a priori* reason to expect that impacts from a wind farm should differ between similar species. Moreover, designing a realistic monitoring programme that can demonstrate differential impacts between, e.g., Red- and Black-throated Divers would be nearly impossible. The extra effort expended in differentiating these species is unlikely to be worth the investment, since it is not expected there would be any difference between species response to the wind farm. For this reason, the similar species are considered as grouped data throughout the report.

2.3 Data analyses

Aerial survey data

After transcription of observation data and flight track data into tables, a combination of ArcGIS/ArcView GIS and TurboPascal software was used to add a position to each bird observation and to assign observations to transect band and side of flight track.

For each survey distribution maps were produced for each of the relevant bird species showing the location and size of the observed flocks. Total bird numbers in each survey were obtained from simple addition of all observations and in comparison between different surveys, bird numbers were corrected for total transects length covered.

For all relevant species, distribution maps based on pooled data from all six surveys conducted during the base-line and construction period are presented for the study area with a resolution of 2x2 km. The maps are corrected for variation in survey coverage

Presentation of bird densities is coupled with methodological problems related to varying coverage of transects and varying transect length (see above), and from a decreasing probability of detecting a bird with increasing distance from the aircraft (see Noer et al. 2000 for a more detailed discussion) that have not been corrected for. Therefore, the analyses are based on the observed numbers and describe the relative densities.

Methods used previously during the base-line study are only presented briefly here. For more details see Noer et al. (2000), Christensen et al. (2001, 2002).

To assess the numbers of birds of the different species that would be susceptible to potential disturbance effects from the wind turbines, and to assess the importance of wind farm area and the adjacent waters, we describe bird preference for the wind farm area and different adjacent zones of potential impact relative to their preference for the whole study area (Fig. 3). For these zones the preference of the most numerously occurring species was calculated using Jacobs selectivity index (Jacobs 1974).

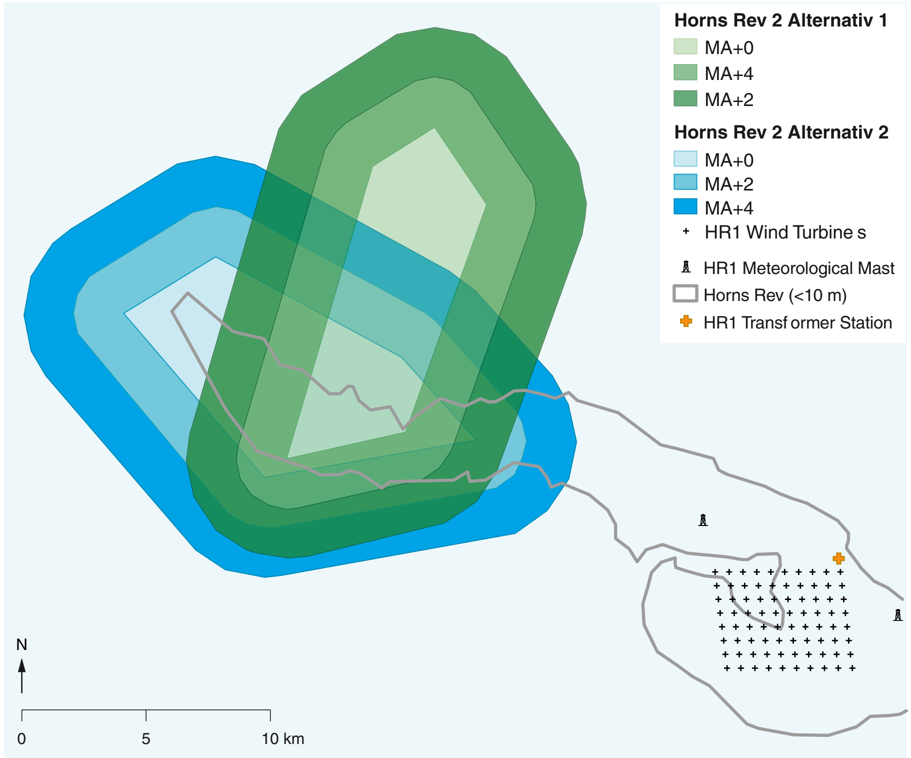

Figure 3. The proposed Horns Rev 2 (Alternative 1) wind farm site and the Alternative 2 wind farm site, with indication of the extends of a 2 km and a 4 km zone around the wind farm sites.

Jacobs selectivity index (D) varies between –1 (all birds present outside the area of interest) and +1 (all birds inside the area of interest), and is calculated as:

$$D = \frac{(r - p)}{(r + p - 2rp)}$$

where r = the proportion of birds in the area of interest compared to the birds in the whole study area, and p = the proportion of the transect length in the area of interest compared to the total transect length in the whole study area. The difference between the two proportions is tested as the difference between the observed number of birds in the area of interest and the number expected in this area, estimated from the share of the length of transect in relation to transect length in the total area (one-sample χ^2-test).

As the period of construction did not include an August survey it was not possible to assess disturbance effects for species which have peak occurrence at this time of the season, e.g., Gannet *Sula bassanus*, Arctic/Common Tern, Sandwich Tern *Sterna sandvicensis*, Common Gull *Larus canus* and Black-headed Gull *Larus ridibundus* (cf. Table 2).

To assess the minimum detectable change in bird numbers within and close to the wind farm area, we applied a χ^2 two-sample test to the numbers recorded within the wind farm area and within the wind farm and +2 and +4 km zones during the base-line years compared against varying reductions and increases. Similarly χ^2 two–sample tests were used to elucidate potential disturbance effects during the period of construction compared to the base-line. In cases the period of construction compared to the base-line. In cases when bird numbers were too small to allow a χ^2-tests, Fisher's exact test was applied (SAS Institute 1999-2001). In all χ^2-tests a Yates correction was used to make a continuity adjustment.

Spatial modelling of Common Scoter densities

Amongst the most numerous species present in and around the vicinity of the Horns Rev 2 proposed project areas, only the Common Scoter occurred in numbers exceeding the thresholds for international importance. Since Danish waters are of outstanding importance as moulting and wintering quarters for a very large proportion of the Western Palearctic population of this species, Denmark has a particular responsibility for the protection and maintenance of habitat of this species. For this reason, a much more detailed analysis of the precise spatial distribution and abundance of this species have been undertaken using more complex analytical techniques, known as spatial modelling, than have been applied to other species where numbers are very much lower and therefore are far less likely to be of national or international concern. Spatial modelling has been used in this instance to estimate bird abundance (in this case Common Scoter) on a density basis (in this case the number of birds in each of a grid of 500 x 500 m squares covering the entire study area) based on the aerial transect survey data. Counts were adjusted for observers, count conditions and spatial heterogeneity in the detectability of birds using standard methods of distance sampling techniques, and these data were subject to spatial modelling using spatially explicit environmental parameters (in this case water depth for all observations obtained from Farvandsvæsnet, because this parameter has such a powerful influence on the distribution of scoters) as covariates to create a bird density surface. By generating such a grid of bird densities, it becomes easier to model the precise distribution of birds (including in areas between the transect tracklines not detected by the count aircraft) throughout the entire survey area, and hence to assess the precise numbers of birds within the proposed wind farm areas. A brief overview of the methods used here follow, but more details can be obtained from the authors on request.

Bathymetric data were made available from the Farvandsvæsenet. Depth frequency distribution was calculated for Common Scoter, weighed by cluster size. The corresponding depth frequency distribution for the survey track was calculated using points at five seconds interval along track lines. It would appear from a visual inspection of the bathymetric data that there are some erroneous depth values in some places south-east of the proposed wind farm. This source of error was not considered to have an significant influence on the results presented in this report.

A software for modelling bird densities and spatial distribution was developed in close collaboration with the RUWPA group at the University of St. Andrews, Scotland. This custom-built software was made in the statistical free-ware "R". The basic principle built on a version of the 'count' model described in Hedley *et al*. (1999), a two-stage model incorporating variability in detectability (with perpendicular distance, and other covariates) and spatial variability in density.

(i) Detection function estimation

The data from the survey were collected in three perpendicular distance interval bins: 44-163 m; 163-432 m; and 432-1000 m. An area from 0-44 meter below the aircraft was not available for searching, for which reason a left-truncation is necessary. Two possible methods are available for analysing left-truncated line transect data. One is to specify the left truncation point - which serves to mark the leftmost point on the distance histogram – and extrapolate the fitted detection function back to zero distance. The other is to subtract the left truncation point (LW) from all observed distances, and analyse the data as if they were on (0, RW-LW) rather than (LW, RW), where RW is the right truncation distance. In this analysis, the latter approach was adopted, and thus the perpendicular distances were analysed as being grouped in three bins: 0-119 m; 119-388 m; and 388-956 m.

Estimation of the detection function was carried out allowing for the effect of covariates to be incorporated into the model. This was achieved by setting the scale parameter as an exponential function of the covariates (Marques 2001). In this case it is assumed that the covariates may affect the rate at which detectability decreases as a function of distance, but not the shape of the detection function. For this exercise we used the half-normal model.

A forward stepwise selection procedure was adopted to decide which covariates to include in the model. First, a model containing perpendicular distance only (null model) was fitted, and its Bayes Information Criterion (BIC; Schwarz 1978) value computed. BIC was used in preference to AIC as it tends to favour lower dimensional models (Schwarz 1978). Covariates (factors or continuous explanatory variables) thought from exploratory data analysis and/or prior intuition to influence detection probability, were then added sequentially to the null model, and the BIC values for each new model were computed. A reduction in BIC indicated a better model fit; the covariate which produced the largest reduction in BIC (if any) was then added to the model. Although this procedure can be repeated until no new covariates are selected, in this analysis we restricted the maximum number of additional covariates to two. Beyond this number, the model-fitting became computationally expensive, with little apparent.

The following covariates were included in the detection function model: Observer, cluster size (number of individuals in a flock) and sea state.

(ii) Spatial modelling of density

We applied the 'count model' of Hedley *et al*. (1999) to model the trend in spatial distribution of Common Scoters at Horns Rev. The response variable was the estimated number of individual birds in segment i, $\hat{N}_i$, estimated using the Horvitz-Thompson estimator (Horvitz & Thompson 1952):

$$\hat{N}_i = \sum_{j=1}^{n_i} \frac{s_{ij}}{\int \hat{g}_{ij}(x,z)\pi(x)\,dx}, \qquad i = 1,\ldots,v, \qquad (1)$$

where n_i is the number of flocks detected in segment i, s_{ij} is the observed number of scoters in flock j in segment i, $\int \hat{g}_{ij}(x,z)\pi(x)\,dx$ is its estimated probability of detection assuming that the probability density function (pdf) of perpendicular distances, x, is uniform with respect to the survey tracklines (and is obtained from the fitted model for the detection function), z being its covariate attributes (used in the detection function model), and v is the total number of segments. In this analysis, most segments were of approximate length 243 m, corresponding to a time interval of about 5 seconds.

A generalized additive model (GAM) with spatially referenced covariates was used to model the response, with the following general formulation:

$$E\left[\hat{N}_i\right] = \exp\left[\ln(a_i) + \beta_0 + \sum_{k=1}^{q} f_k(z_{ik})\right], \qquad i = 1,\ldots,v. \qquad (2)$$

Here a_i is an offset that corresponds to the area of the ith segment. β_0 denotes the intercept, and the f_k is a two-way interaction between the geographic covariates, X and Y, incorporated via a two-dimensional smooth (fitted using thin plate splines) (Wood in press). The formulation shown in equation (2) assumes a logarithmic link function for the GAM; an appropriate form for the variance-mean relationship must be selected according to the data.

Apart from the grid co-ordinates X and Y, the only other covariate used was water depth. Model selection was carried out using Generalised Cross Validation (GCV), as implemented in the *mgcv* package (Wood 2001) within *R*. The decision on whether to include or exclude a term was also made on the basis of diagnostic plots of the smoothed density against each covariate term (Wood 2001). Models that clearly overfitted the data (predicting a few small spurious hotspots of high density, and no birds elsewhere) were excluded either by examination of the fitted spatial density surface, or by considering that the predicted abundance estimates were unrealistically high or low.

(iii) Variance estimation

The current status of the software does not yet permit reliable estimation of variance, and thus estimation of confidence intervals for the derived density estimates could not be performed.

Output from this modelling was used to describe densities and spatial distribution of the Common Scoters on the study area, survey by survey.

Calculation of the potential number of displaced Common Scoters was made under the assumption that the species stays away from the wind farm site and its immediate vicinity (i.e. all 500 x 500 meter grid cells that intercept the area of the wind farm), with a linear, gradually decreasing effect out to a distance of 2 km. In this was the number of displaced Common Scoters could be estimated, given this set of assumptions.

2.4 Quality control

All observations of birds during the aerial surveys were recorded on a dictaphone. During subsequent transcription unusual data were underlined or commented to make a later exclusion of erroneous data possible. After being computerised into databases, all records were checked once again to identify errors during this procedure.

The present report is subject to the following quality control:
- Internal editorial and linguistic revision
- Internal proof-reading
- Layout followed by proof-reading
- Approval by project managers.

3 Results

3.1 Introduction

The Horns Rev - Blåvands Huk area is internationally known for its concentrations of migrating, staging and wintering birds. In relation to the Horns Rev wind farm, these concentrations are most logically split into two subgroups, namely species that moult, stage and winter in the area (i.e. exploit the habitat for foraging), and species that mainly pass through the area during migration. For the latter group, only the collision risk is considered relevant.

Migrating birds concentrate at Blåvands Huk because birds follow the coastline as a navigational guide, particularly during autumn migration. Since autumn population sizes are generally larger than at all other times of the year, due to the presence of young of the year, concentrations of migrants are highest during autumn. A bird observatory was established by the Danish Ornithological Society at Blåvands Huk in 1963, and observations from more than 35 years provide a detailed basis for assessing the phenology, numbers and species migrating through the area (Kjær 2000, Jakobsen in print). Thus, a substantial literature exists, covering the volume and phenology of bird migration in the coastal areas, which includes species associated with both marine and terrestrial habitats.

NERI's general monitoring of the Wadden Sea includes coastal areas south of Blåvands Huk but not areas closer than c. 10 km to the wind farm area. Thus, to date, monitoring data existed from only 2-3 surveys from ship and aircraft during 1987-1989 that cover Horns Rev (Laursen 1989, Laursen et al. 1992, Skov et al. 1995, Laursen et al. 1997).

The recent studies of birds in relation to the Horns Rev 1 wind farm have provided detailed descriptions of bird abundance and distribution in the offshore parts of Horns Rev before during and after the turbines were erected in 2002. These studies also include detailed analyses of bird reactions to the presence of the 80 wind turbines in this wind farm, based on data collected in 2003, 2004 and 2005 (Petersen et al. in print).

Based on these data sources, a summery of the status of bird occurrence around Horns Rev is given in the following section.

3.2 General occurrence of birds in the Horns Rev area

3.2.1 Divers *Gaviidae*

Four species of divers have been recorded in the area. In general, however, divers are difficult to identify to species in the field, and most observations have only be assigned to either 'large divers' (great

Northern Diver *Gavia immer* or White-billed Diver *Gavia adamsii*) or 'small divers' (Red-throated Diver *Gavia stellata* or Black-throated Diver *Gavia arctica*). The two former species occur in Danish waters in very low numbers and will not be dealt with further.

Based on the results from the ship surveys in 1999, 78% of the identified divers were Red-throated and 22% Black-throated Divers. These figures are consistent with earlier findings (Joensen & Hansen 1977, Jakobsen in print.).

Red- *Gavia stellata* and Black-throated Diver *G. arctica*

Spring migration at Blåvands Huk takes place during April-May when up to 6,000 divers have passed on a single day. Autumn migration takes place during October-November and is less concentrated with up to 1,000 birds per day (Jakobsen in print.). Observations of 5,000-6,000 divers per day in March migrating south are considered to be wintering birds compensating for nocturnal drift caused by wind and current.

Aerial and ship surveys carried out during 1987-1989 demonstrated that the area off the Wadden Sea north and south of Horns Rev (c. 6,000 km^2) held internationally important numbers of divers during autumn, winter and spring (Laursen et al. 1997). The estimated autumn population was 1,700-2,200 birds. During winter up to 4,500 individuals have been estimated in the southeast North Sea (Laursen & Frikke 1987), while in spring, up to 28,500 birds were estimated to be present in the area (Laursen et al. 1997).

The studies at the Horns Rev 1 wind farm 1999-2005 recorded a total of 3,919 divers. Maximum numbers were recorded in February, March and April, with some high numbers occasionally recorded in November and December. Most divers were recorded in the area north- and southwest of the wind farm area, with a few high counts in the coastal zone around Blåvands Huk (Petersen et al. in print).

Rose & Scott (1997) estimated flyway population sizes at 75,000 Red-throated and 170,000 Black-throated Divers.

3.2.2 Grebes *Podicipitidae*

Great Crested Grebe *Podiceps cristatus*

The Great Crested Grebe occurs as an autumn migrant at Blåvands Huk, with occasional records of winter movements during periods of cold spells (Jakobsen in print.).

Red-necked Grebe *Podiceps grisegena*

Red-necked Grebe is the most numerous grebe recorded on migration at Blåvands Huk. Most birds are recorded during autumn migration during September-November (Kjær 2000). Highest numbers recorded have been 107 birds/day (Jakobsen in print.).

The area off Blåvands Huk was previously considered an important wintering area for Red-necked Grebe. Skov et al. (1995) estimated a wintering population of ca. 200 birds in the area of Horns Rev, while Laursen et al. (1997) found a density of 0.1-0.99 birds/km^2, suggesting that up to c. 650 Red-necked Grebes could winter in the area.

The studies at the Horns Rev 1 wind farm 1999-2005 recorded only 9 Red-necked Grebe in the Horns rev area (Petersen et al. in print).

Rose & Scott (1997) estimated a flyway population of 15,000 Red-necked Grebes.

3.2.3 Gannet *Sula bassanus*

At Blåvands Huk the first Gannets are observed in July and the peak migration takes place September-October with up to 4,000 birds/day (Jakobsen in print.). The occurrence at the coast is primarily related to periods of strong westerly winds pushing the birds close to Blåvands Huk. It is assumed that some movements in the area take place in relation to food availability (following shoals and the local abundance of fish), since a substantial proportion of the birds is flying north (Jakobsen in print.).

According to Laursen et al. (1997) the Gannet is widespread in the North Sea outside the winter. In the Danish part of the North Sea in the late 1980s the estimated number of birds ranged from none in winter to 22,000 birds in late summer and autumn. The estimate of 22,000 birds is probably an overestimate as the Gannet may be attracted to the ships used in surveys (Laursen et al. 1997).

The studies at the Horns Rev 1 wind farm showed maximum numbers of Gannets during April-September.

The studies at the Horns Rev 1 wind farm 1999-2005 recorded a total of 1,144 Gannets. Maximum numbers were recorded during April-September. Most Gannets were recorded in the area west of the wind farm area, but Gannets also occurred close to land around Blåvands Huk (Petersen et al. in print).

3.2.4 Eider *Somateria mollissima*

The Eider occurs in the Wadden Sea area and at Blåvands Huk at all times of the year. Staging and wintering birds are rarely observed north of Blåvands Huk. The species has a rather coastal distribution and a large part of the birds are found in the waters between the mainland and the islands of Fanø, Manø, and Rømø (Laursen et al. 1997).

During the winter period up to 35,000 Eiders have been recorded in the Blåvands Huk area, with highest numbers occurring during severe winters (Jakobsen in print.). Up to 40,000 Eiders were present in the southeastern part of the North Sea during the severe winter of 1986 (Laursen & Frikke 1987). The number and distribution of wintering birds are probably influenced both by winter conditions (ice cover in the Wadden Sea forcing the birds into deeper offshore waters), and availability of the main prey, Common Mussel *Mytilus edu-*

lis, in the Wadden Sea (Jakobsen in print.), but probably also affected by ice cover in the inner Danish waters (Laursen & Frikke 1987). At Blåvands Huk, the Eider migration takes place during February-March and October-November, which may account for up to 30,000 birds/day (Jakobsen in print.).

The studies at the Horns Rev 1 wind farm 1999-2005 recorded a total of 27,718 Eiders. Maximum numbers were consistently recorded in February, but with occasional high counts in November and December. Most Eiders were recorded in the coastal areas around Blåvands Huk, Skallingen, with only a very few records of birds in the offshore parts of the study area (Petersen et al. in print).

Rose & Scott (1997) estimated the flyway population size at 1.35 - 1.7 million Eiders.

3.2.5 Common scoter *Melanitta nigra*

The Common Scoter occurs in the Wadden Sea area and at Blåvands Huk at all times of the year. During June-July thousands of Common Scoters undertake a moult migration to the shallow areas west of Rømø, Fanø and Skallingen where they moult their flight feathers and other parts of their plumage and are flightless for a period of 2-3 weeks. Joensen (1973) recorded 100,000-150,000 flightless scoters in late July 1963 in the area between Blåvands Huk and Rømø, while Laursen et al. (1997) estimated 11,400-70,900 moulting scoters in the area west of the Danish Wadden Sea during 1987-1989. Moulting birds are normally to be found in remote offshore waters far from the coast. Pre-moulting Common Scoters have been observed at Blåvands Huk in numbers up to 20,000 birds in June (Jakobsen in print).

After completion of moult, a substantial part of the aggregation is assumed to migrate further south along the west coast of Europe (Laursen et al. 1997). The area west of the Wadden Sea is, however, an important staging area during autumn migration, supporting more than 100,000 Common Scoters (Laursen et al. 1997). At Blåvands Huk autumn migration peaks during August-September with a daily maximum record of 60,000 birds (Jakobsen in print). Laursen et al. (1997) report that - although numbers fluctuate - up to 120,000 birds may winter off the Wadden Sea, while observations at Blåvands Huk show a more stable number of 25,000-40,000 Common Scoter in this area visible from land (Jakobsen in print.). Laursen et al. (1997) report that the highest numbers occur off the Wadden Sea during severe winters, which is the factor assumed to be responsible for the maximum numbers recorded (>200,000) at Blåvands Huk in 1984 and 1985 (Jakobsen in print) and 170,000 counted from aircraft in the southeast North Sea during the severe winter of 1986 (Laursen & Frikke 1987).

Spring migration of Common Scoters in Denmark takes place in the period March-May according to Salomonsen (1972). However, spring migration is less pronounced, since the majority of Common Scoters migrate directly over land from the Wadden Sea to the Baltic Sea during the night (Cramp & Simmons 1977). Laursen et al. (1997) estimated that up to 50,000 Common Scoters were present in the area west of the Wadden Sea in spring.

Based on the numbers recorded during the 1987-1989 surveys (Laursen et al. 1997), the offshore area from Blåvands Huk to Rømø has been assigned as an internationally important staging area for moulting, autumn migrating and wintering Common Scoters, but is a less important staging area in spring.

The studies at the Horns Rev 1 wind farm 1999-2005 recorded a total of 917,700 Common Scoters. Maximum numbers were consistently recorded during the period November to April. The distribution of Common Scoters in the study area showed marked annual and seasonal changes. The area off Skallingen and Blåvands Huk was consistently used by birds during the wintering period, whereas the areas of the southeast, and in the later years, the western parts of the Horns Rev were important especially during spring (Petersen et al. in print).

Rose & Scott (1997) estimated the flyway population size at 1.6 million Common Scoters.

3.2.6 Skuas *Stercoraridae*

Four species of skuas occur regularly in the North Sea. Of these, arctic Skua is far the most numerous species, but is, however, difficult to distinguish from both Pomarine and Long-tailed Skua. 86 records of positively identified skuas from the ship surveys resulted in 75 (87%) Arctic Skuas, 10 (12%) Pomarine Skuas and 1 (1%) Long-tailed Skua, while no separation was made during aerial surveys.

At Blåvands Huk skuas are observed in relatively small numbers with Arctic Skua as the most common with up to 200 birds/day in late August - mid September (Jakobsen in print). Great Skua *Stercorarius skua* is regularly observed during late summer and autumn with 20 birds as a daily maximum. Pomarine Skua and Long-tailed Skua are only observed irregularly, but may in some years occur in high numbers.

The studies at the Horns Rev 1 wind farm 1999-2005 recorded a total of 66 skuas, mainly Arctic Skua. Most birds were recorded in August and September, when skuas undertake migration through Danish waters (Petersen et al. in print).

3.2.7 Gulls *Larinae*

Gulls are widely distributed and occur in large numbers in the Horns Rev and Blåvands Huk area at all times of the year. The Black-headed Gull *Larus ridibundus* is primarily associated with inshore waters. Little Gull *Larus minutus*, Common Gull *Larus canus*, Herring Gull *Larus argentatus*, Lesser Black-backed Gull *Larus fuscus*, and Great Black-backed Gull *Larus marinus* occur both in inshore and offshore waters. Kittiwake *Rissa tridactyla* occurs mainly in offshore waters, but with strong westerly winds many birds show up at Blåvands Huk.

Little Gull ***Larus minutus***

The Little Gull occurs in the North Sea only in the area west-northwest of Blåvands Huk. Based on the offshore surveys during 1987 to 1989, the estimated numbers in this area reached 3,100 individuals in autumn and 850 in winter and spring (Laursen et al. 1997). At Blåvands Huk up to 200 birds/day passing in January-April are considered as wintering birds, since spring migration takes place during late April and May. Autumn migration takes place in October-November with a maximum of 600 birds/day (Jakobsen in print).

The studies at the Horns Rev 1 wind farm 1999-2005 recorded a total of 1,451 Little Gulls. Maximum numbers were consistently recorded during March and April. The distribution of Little Gull was variable, but most birds were recorded in the offshore parts of the area (Petersen et al. in print).

Rose & Scott (1997) estimated the Central/Eastern European population to be 60,000-90,000 Little Gulls. The birds wintering in the North Sea region originate from this population.

Herring Gull ***Larus argentatus***

The Herring Gull is very common in the area. At Blåvands Huk 15,000-20,000 birds can be seen during winter. Spring migration starts in late February, but the numbers remain high until May with up to 5,000-7,000 birds/day due to the presence of non-breeding immature and sub-adult birds. From late summer the numbers increase until November, with a maximum peak of 23,000 birds/day (Jakobsen in print).

The studies at the Horns Rev 1 wind farm 1999-2005 recorded a total of 45,974 Herring Gulls. Maximum numbers were consistently in February, but with occasional high counts in March-April and August-November. The distribution of Herring Gull was mainly coastal, but with offshore occurrences associated with fishery activities (Petersen et al. in print).

Rose & Scott (1997) estimated the northwestern European population to be 1.4 million Herring Gulls.

Great Black-backed Gull ***Larus marinus***

The Great Black-backed Gull occurs at Blåvands Huk throughout the year. Highest numbers are recorded during summer and autumn with up to 750 birds/day present (Jakobsen in print). The species seems to be more pelagic during autumn and winter than during spring and summer (Skov et al. 1995).

The studies at the Horns Rev 1 wind farm 1999-2005 recorded a total of 1,125 Great Black-backed Gulls. Maximum numbers were recorded during August and September. The distribution of Great Black-backed Gull was variable, but birds were recorded both in the offshore parts of the area and in the coastal areas (Petersen et al. in print).

Rose & Scott (1997) estimated the northeastern Atlantic population to be 480,000 Great Black-backed Gulls.

Kittiwake *Rissa tridactyla*

The estimated number of Kittiwakes in the North Sea in late summer is 13,000-34,000 birds, in autumn 45,000-115,000 birds, and in winter 34,000-95,000 birds. Highest densities normally occur in the northern parts of the North Sea along the Norwegian Trench (Laursen et al. 1997). Kittiwakes are observed at Blåvands Huk mainly during summer and autumn when up to 5,000 birds/day may be seen from late August to late October (Jakobsen in print). In spring, the occurrence of Kittiwake is normally associated with strong westerly winds (Skov et al. 1995).

The studies at the Horns Rev 1 wind farm 1999-2005 recorded a total of 3,518 Kittiwakes. Maximum numbers were consistently recorded in March and during August-November. The distribution of Kittiwakes showed that most birds occurred in the offshore parts of the area (Petersen et al. in print).

Rose & Scott (1997) estimated the eastern Atlantic population at 8.4 million Kittiwakes.

3.2.8 Terns *Sterninae*

Discrimination between Arctic and Common Tern is only possible at close range and under optimal conditions. Of 346 identified terns during the ship surveys 209 (60%) were Arctic Tern and 137 (40%) were Common Tern. Although there is some difference in their temporal occurrence, observations of the two species are lumped.

Arctic Tern *Sterna paradisaea* and Common Tern *S. hirundo*

The Arctic and Common Tern arrive in Danish waters in April, and spring migration peaks in late April - early May, when up to 5,000 birds/day can be observed at Blåvands Huk (Jakobsen in print). Autumn migration occurs in July-August with records of up to 17,000 birds/day (Kjær 2000).

The studies at the Horns Rev 1 wind farm 1999-2005 recorded a total of 3,279 Arctic/Common Tern. Maximum numbers were consistently recorded during April-May and August-September, reflecting spring and autumn migration periods. The distribution of terns were highly variable, but with the most marked concentrations of birds recorded in the central offshore parts of Horns Rev and around Blåvands Huk (Petersen et al. in print).

Rose & Scott (1997) estimate the European population of Common Tern to be 780,000 birds. There is no estimate for the Arctic Tern available.

Sandwich Tern *Sterna sandvicensis*

The Sandwich Tern normally occurs at Blåvands Huk from March to October. Highest numbers are observed during migration with up to 1,800 birds/day in April-May and up to 6,000 birds/day in July-August (Jakobsen in print). The species breeds on Langli in Ho Bight with up to 1,350 pairs in 1997 and 1998 (Laursen 1999) and birds from the colony probably forage in the North Sea off Skallingen and Blåvands Huk.

The studies at the Horns Rev 1 wind farm 1999-2005 recorded a total of 1,066 sandwich terns. Maximum numbers were consistently recorded in April and during August-September. The distribution of Sandwich Terns showed birds both offshore and in the coastal parts of the area (Petersen et al. in print).

Rose & Scott (1997) estimated the western European and western African population at 150,000 Sandwich Terns.

3.2.9 Auks *Alcidae*

Guillemot *Uria aalge* and Razorbill *Alca torda*

According to Laursen et al. (1997) the Guillemot is more abundant and widely distributed in the North Sea than the Razorbill. In the German Bight the late summer population was estimated to be 4,500-20,000 Guillemots increasing to 15,000-30,000 birds in autumn. The numbers of Razorbill were estimated at 100-1,700 birds during autumn, increasing to 4,200 birds in winter.

At Blåvands Huk both Guillemot and Razorbill are most numerous during October-November with up to 1,500 birds/day counted. Smaller numbers occur during winter from December to February (Jakobsen in print.).

The studies at the Horns Rev 1 wind farm 1999-2005 recorded a total of 2,430 Guillemots/Razorbills. Maximum numbers were recorded during February-March and during the August-November. The distribution of auks was variable, but most birds were recorded in western and southern central parts of the study area (Petersen et al. in print).

According to Lloyd et al. (1991) the northwestern European population of Guillemots is estimated to be 1.5 million birds and that of Razorbill 200,000 birds.

3.3 Studies of bird behaviour towards wind farms

Given that the number of large operational offshore wind farms worldwide is very small, (although several more are planned and some are even under construction), published data on bird exploitation of the waters within wind farm areas, bird behavioural responses (i.e., avoidance or attraction towards offshore wind turbines), and assessments of the potential risk of colliding with wind turbines is presently very limited. Specific studies of bird reactions to offshore wind farms have, however, been performed on some relatively small offshore wind farms (≤ 10 turbines) constructed in Denmark (Guillemette et al. 1997, 1998, 1999, Guillemette & Larsen 2002, Tulp et al. 1999) and in Sweden (Pettersson 2005). Most recently, the results of detailed bird studies in relation to two large offshore wind farms at Horns Rev (80 turbines) and Nysted (72 turbines) in Denmark have latterly become available (Petersen et al. in print). Other studies that have described the behaviour of waterbirds in relation to wind farms have generally been performed in relation to small semi-offshore wind farms (e.g., Dirksen et al. 1998) or wind farms situated in terrestrial habitats (e.g., Pedersen & Poulsen 1991, Percival 1998, Larsen & Madsen 2000).

In the following sections, the main conclusions of these studies will be briefly presented. As the construction of the Horns Rev 2 offshore wind farm will take place close to Horns Rev 1, emphasis is put on this location, as there will be an almost complete overlap in species account between these two wind farms.

3.3.1 Exploitation of wind farm areas by resting and staging birds

An analysis of the extent of "effective habitat loss" which results from behavioural avoidance shown by birds to wind turbines has been undertaken at many terrestrial wind farms using some measure of the distribution of feeding and resting birds prior to construction in comparison with those under post construction conditions. Very few of these studies are published in the scientific literature, but Larsen & Madsen (2000) were the first to demonstrate that many landscape and habitat features caused an effective habitat loss of 68% of the total area of an agricultural landscape. Their study showed that because geese would not come within 100 m of individual turbines, of the remaining area available, a further 13% of suitable habitat was effectively "lost" because of the reticence of geese to approach any closer to the turbines.

At the two large offshore wind farms recently constructed in Danish waters, effective habitat loss was measured by comparing data on the bird distributions obtained by aerial surveys before and after construction of the Horns Rev and Nysted wind farms. Based on these analyses, Petersen et al. (in print) made the following general conclusions:

1. that the most numerous species generally demonstrated avoidance behaviour in their distribution patterns at both of the two Danish offshore wind farms (most notably divers, Common Scoter and Long-tailed Ducks), although the responses are highly species specific.

2. that no bird species demonstrated enhanced use of the waters within the two Danish offshore wind farms.

Petersen et al. (in print) acknowledged that although the displacement of birds as a result of behavioural avoidance of the wind farms represents effective habitat loss, it is important to assess the relative loss in terms of the proportion of potential feeding habitat (and hence the proportion of birds) affected relative to the areas outside of the wind farm. For most of the species recorded at Horns Rev and Nysted, that proportion was relatively small and therefore likely of little biological consequence. However, where birds are highly concentrated into small areas likely to be heavily affected by wind farm developments, the local effect may be substantial.

3.3.2 Wind farms as obstacles to migrating birds

Based on data obtained by radar and by visual observations at the Horns Rev 1 and the Nysted offshore wind farms, Petersen et al. in print made the following general conclusions:

1. that birds generally demonstrate avoidance behaviour at both of the two Danish offshore wind farms, although the responses were highly species specific,

2. that the proportions of birds approaching the wind farm area post construction crossing the wind farm area have decreased relative to the pre-construction baseline (Nysted wind farm).

3. that these patterns reflect birds making (i) gradual and systematic modification to their flight routes in response to the visual stimulus of the wind farm, with (ii) more dramatic changes in flight deflection close to the outermost turbines.

4. that changes in flight direction occurred closer to the wind farm at night, and that because it is more difficult for migrating birds to detect the wind farm at night, the proportion of birds crossing the wind farm will be greater at night than by day.

5. that too few observations of intense migratory movements were made during periods of poor visibility to enable an assessment of visibility, an thus that no major conclusions could be drawn about poor visibility (e.g. as a result of fog or precipitation) affecting the avoidance response,

6. that the observations did not strongly support the alternative hypothesis that some flying birds of certain species show a lateral attraction response to the wind farm.

Consequently, Petersen et al. (in print) stressed that the response patterns shown by waterbirds in general, and at Nysted by Eiders in particular, resulted in most migrating birds avoiding the wind farms, although it was clear that the avoidance responses were highly species specific, that individuals show different responses to wind farms and that all birds could potentially enter the wind farms. At Horns Rev 1, some species were almost never witnessed flying between the turbines despite their abundance outside (e.g. divers and Gannets), others rarely did so (e.g. scoters) or were generally avoiding flying a long way into the wind farm (e.g. terns), whilst others (e.g. gulls, especially Greater Black-backed and Herring Gulls) showed no sign of avoidance at all (Petersen et al. in print).

Similar patterns of migrating birds (mainly Eiders) avoiding wind turbines have been found by Pettersson (2005) at the two Swedish wind farms. He also found that deflection occurred at a longer distance to the wind farm in good visibility than during reduced visibility, e.g., during night.

3.3.3 Risk of collisions

Based on the results from the radar studies of bird movements at both the Horns Rev 1 and Nysted wind farms and from surveillance by an infrared camera (TADS-study) at the Nysted wind farm, Petersen et al. (in print) made the following conclusions:

1. that many bird species showed avoidance responses at distances of up to 5 km (and potentially more) from the turbines, and within a range of 1-2 km, that more than 50% of birds heading for the wind farm avoid passing within it,

2. that most birds entering the wind farm re-orientate to fly down between turbine rows, frequently equidistance between turbines, further minimising their risk of collision, and that many birds readjust flight orientation once within the wind farm to take the shortest exit route, further minimising collision probability,

3. that waterbirds (mostly Eider) reduce their flight altitude within the wind farm, flying more below rotor height than they do outside the wind farm.

Using a stochastic predictive collision model to estimate the numbers of Eiders, the most common species in the area, likely to collide with the sweeping turbine blades each autumn at the Nysted offshore wind farm, Petersen et al. (in print) predicted with 95% certainty that out of 235,000 passing Eiders, 0.018-0.020% would collide with the turbines in a single autumn (41-48 individuals). These calculations were based on parameters derived from radar investigations and TADS, and obtained from 1,000 iterations of the model.

That bird collisions at the Nysted wind farm occurred in very low frequencies, as documented by the TADS surveillance, were somewhat supported by the lack of visual recognition of collisions between birds and turbines at either site. However, given the few hours of effective visual observation, and the *a priory* expectations of low collisions frequencies, visual observations of collisions were not expected from these programmes.

3.4 Bird numbers and distributions

During the period from November 2005 until May 2006 a total of six aerial surveys were performed around the proposed Horns Rev 2 wind farm sites. The survey coverage was very uniform between surveys, with approximately 850 km of transect line covered during each survey. In order to reflect observer effort, survey coverage was weighted by observer effort, so 10 km of survey track line covered by both observers contributes to survey coverage of 20 km (Table 1 and Figure 4).

Table 1. Summed survey coverage by survey for six aerial surveys performed around Horns Rev 2 between November 2005 and May 2006. Survey coverage was weighted by observer coverage.

Date	Km of covered transect line
18./19. NOV 2005	1672
02. FEB 2006	1695
25. FEB 2006	1696
12. MAR 2006	1696
15. APR 2006	1690
11. MAY 2006	1705

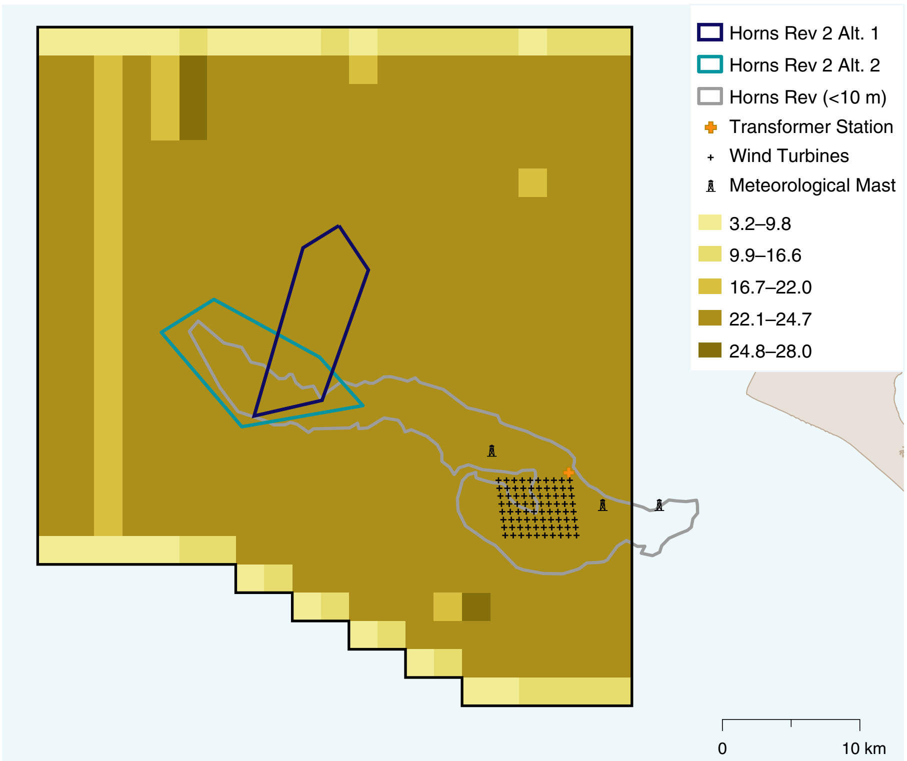

Figure 4. Transect length survey effort (in km) per 2 x 2 km grid squares in the study area, summed for all six surveys performed in the Horns Rev study area. See text for details.

Red-throated/Black-throated Diver

A total of 735 Red-throated/Black-throated Divers were recorded during the six aerial surveys (Table 2). Of these 24% were identified as Red-throated Diver, while only one bird was positively identified as Black-throated Diver.

Table 2. Numbers of birds encountered during six aerial surveys at Horns Rev 2 from November 2005 to May 2006, summed by species/species group and survey date.

Species	Total	18./19. NOV 2005	02. FEB 2006	25. FEB 2006	12. MAR 2006	15. APR 2006	11. MAY 2006
Diver sp.	559	107	20	24	84	185	139
Red-throated Diver	175	5	11	10	74	73	2
Black-throated Diver	1				1		
Grebe sp.	2					2	
Fulmar	22	5	4	5		3	5
Gannet	92	3			2	39	48
Cormorant	3				1	2	
Greylag Goose	15					15	
Long-tailed Duck	8	7		1			
Eider	3				3		
Common Scoter	88810	15224	21888	21111	10252	17759	2576
Velvet Scoter	9	1	2	1	1	4	
Skua sp.	2						2
Common Gull	10	2			6	2	
Herring Gull	1821	111	566	352	253	519	20
Lesser Black-backed Gull	21					19	2
Great Black-backed Gull	44	5		3	1	29	6
Black-headed Gull	1					1	
Little Gull	423	77	34	24	11	266	11
Kittiwake	142	89	25	13	7	3	5
Gull sp.	1132	54	1	2	413	641	21
Arctic/Common Tern	301					70	231
Sandwich Tern	68					32	36
Tern sp.	154					18	136
Auk/Guillemot	684	540	27	34	23	53	7
Auk	49	33		5	10	1	
Guillemot	15	5	1		7	2	

The north-eastern and central northern parts of the survey area clearly attracted the highest concentrations (Figure 5). There was considerable variation in the distribution of divers between surveys, reflecting variations in hydrographical conditions in the area (Figure 6 a-f). In November 2005 most birds were seen in the eastern parts of the study area, while few birds were seen in the north-eastern and northern parts of the area during two surveys in February 2006. In March 2006 many divers were recorded in the north-eastern parts of the study area, with fewer birds dispersed over the general northern parts of the survey area (Figure 6 d). In April 2006 the same pattern of distribution was observed, with few birds found south of the reef (Figure 6 e). In May 2006 the main concentration was found just north of the proposed Horns Rev 2 (Alternative 1) site in the central northern part of the area (Figure 6 f).

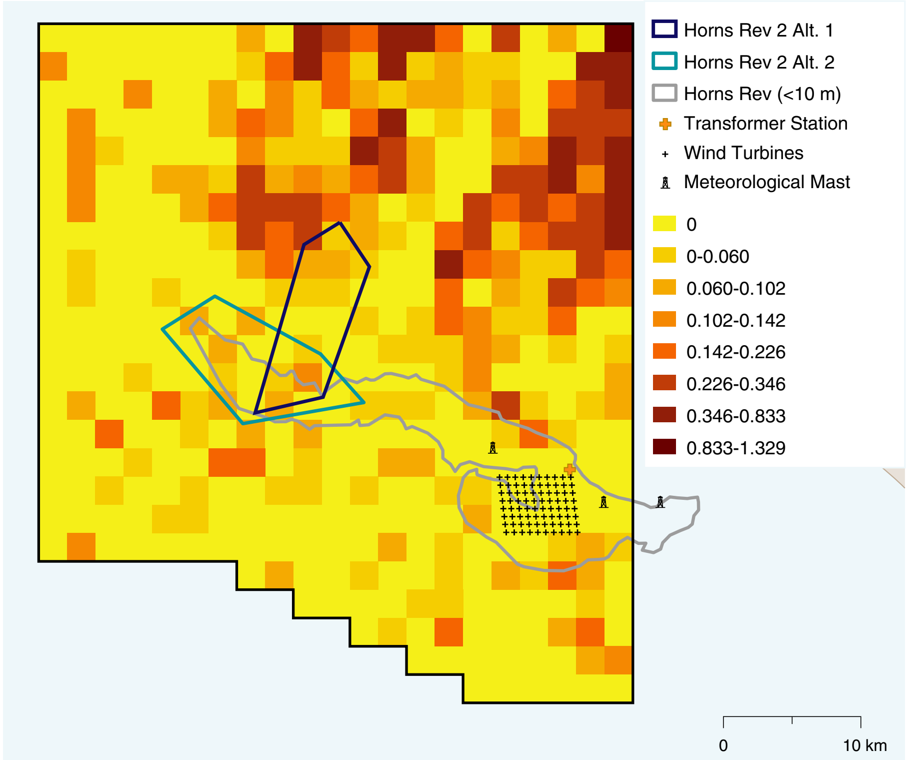

Figure 5. Relative density of Red-throated/Black-throated Diver in the Horns Rev 2 study area, based on six surveys performed between November 2005 and May 2006. Data expressed as number of observed birds per kilometre of flown transect coverage in each 2 x 2 km grid square.

During these surveys, divers utilised the area of the proposed wind farm and the alternative wind farm site less than expected when assuming an even distribution of the 735 encountered birds (Tables 3 and 4). D-values of -0.14, -0.15 and -0.05 for the wind farm site and when including the 2 and 4 km zones respectively showed a slight a avoidance of the area, but the difference was not significant. The corresponding D-values for the alternative wind farm site showed a more pronounced and significant avoidance of that area by divers as compared to the general distribution across the survey area, with values of -0.38, -0.50 and -0.46 for the three above distance categories.

These findings are different from results obtained during the bird surveys in connection with Horns Rev 1, where highest concentrations of divers were found in the general area of the proposed Horns Rev 2 wind farm and the alternative site (Petersen et al. in press).

Skov and Prins (2001) described diver distributions in the German Bight and their relation to hydrographic fronts, with elevated diver densities described for the area around Horns Rev.

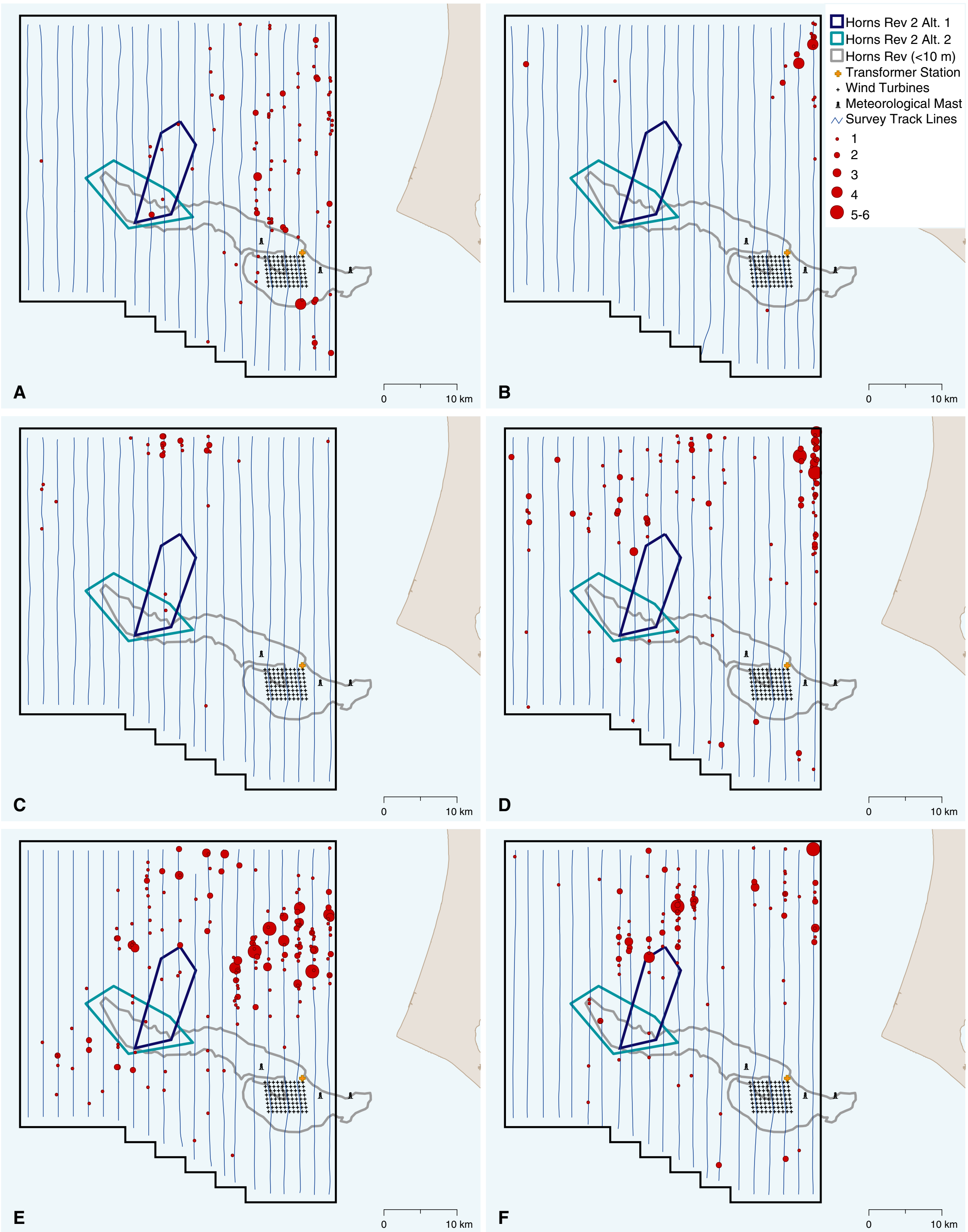

Figure 6. Numbers and distribution of Red-throated/Black-throated Diver in the Horns Rev 2 study area during each of six aerial surveys, 18 and 19 November 2005 (a), 2 February 2006 (b), 25 February 2006 (c), 12 March 2006 (d), 15 April 2006 (e) and 11 May 2006 (f). The flown track line of each survey is shown. The 10 m depth contour around Horns Rev is indicated and the Horns Rev 1 wind turbines, transformer station and meteorological masts are shown.

Gannet

A total of 92 Gannets were recorded in the study area during the six aerial surveys, most (48) during May 2006 (Table 2). Gannets pursue schools of fish from relatively high altitude, so it is likely that their distribution in the survey area reflects prey availability, and since fish schools are highly mobile and can vary in species composition, the distribution of gannets was highly variable. During a survey in April 2006 Gannets were mainly seen in the western parts of the survey area, while they were dispersed over most of the area during the May 2006 survey (Figure 7 a-b).

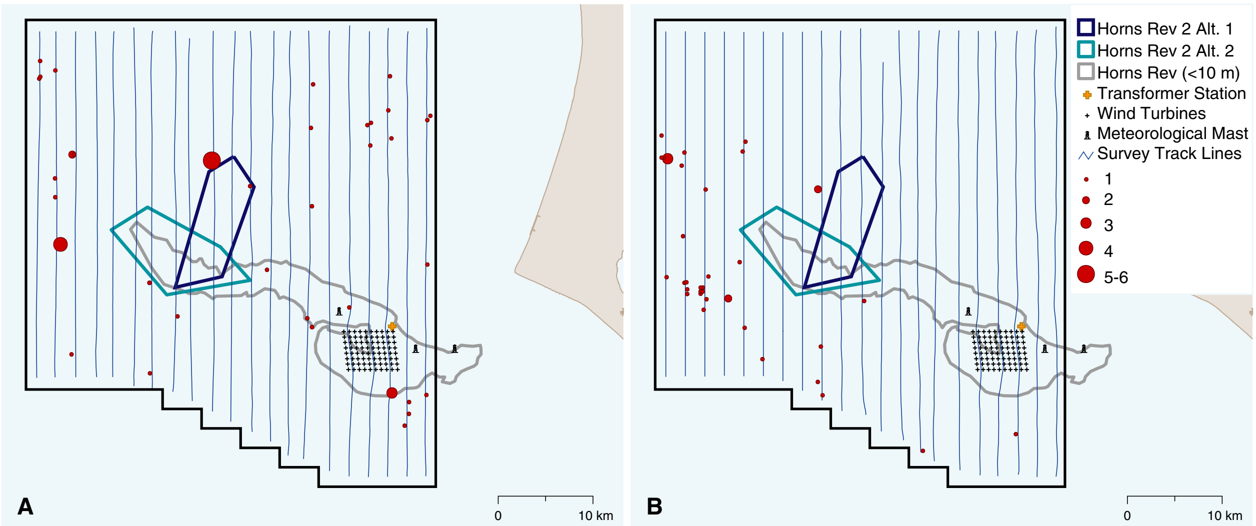

Figure 7. Numbers and distribution of Gannet in the Horns Rev 2 study area during two aerial surveys, 15 April 2006 (a) and 11 May 2006 (b).

Gannets avoided the proposed Horns Rev 2 wind farm site, based on data from these six surveys, but showed little or no selection or avoidance when including the 2 and 4 km zones around the site, with D-values of -0.51, +0.12 and 0.00 respectively for the three zones (Table 3). The corresponding values for the alternative wind farm site were -1.00, -0.48 and -0.24, which indicates a higher degree of avoidance of this site as compared to the proposed site (Table 4). None of the above index calculations reached significant levels.

Data from investigations of birds in connection with the Horns Rev 1 wind farm showed that Gannets were most abundant in the area from April into October and that the western parts of the Horns Rev 1 study area had the highest concentrations of Gannets, including the area of the proposed Horns Rev 2 wind farm and the alternative site (Petersen et al. in print).

Common Scoter

With a total of 88,810 observed Common Scoters during the six aerial surveys this species was by far the must abundant species in the survey area (Table 2). The main concentrations were in the central part of the survey area, extending into the central northern parts. Smaller aggregations were found just to the northwest of the Horns Rev 1 wind farm and in the north-eastern part of the area (Figure 8). Only

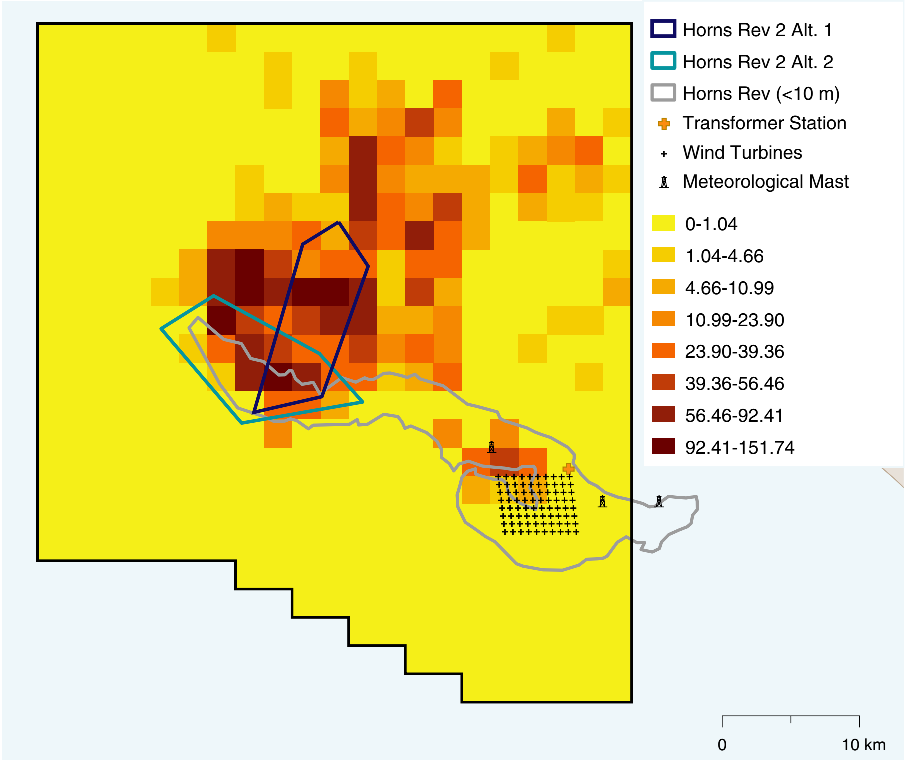

Figure 8. Relative density of Common Scoter in the Horns Rev 2 study area, based on six surveys performed between November 2005 and May 2006. Data expressed as number of observed birds per kilometre of flown transect coverage in each 2 x 2 km grid square.

relatively rarely were Common Scoters recorded outside these areas. The variation in distribution between surveys was small, even though some differences in location within the described areas of high concentrations was observed (Figure 9 a-f).

In the coastal areas off Skallingen and Fanø high numberes of Common Scoters were recorded during the surveys carried out in connection with the Horns Rev 1 investigations. These areas were not surveyed during the present study. In one occasion in December 2005 the entire Horns Rev 1 and Horns Rev 2 survey areas were covered within two consecutive days. In that particular case 42% of the Common Scoters recorded were found at Horns Rev, while 58% were recorded in the coastal areas.

Common Scoters have changed their patterns of distribution within the Horns Rev 1 survey area through the period of the investigations of birds from 1999 till 2005. After the experience from the first years of the investigations (1999 till 2002) a seasonal pattern emerged of birds concentrating close to land from September until January/February, but thereafter showing a gradual movement towards the south-eastern parts of Horns Rev from March through April (Christensen et al. 2003, Petersen et al. 2004). In March and April 2003 this general movement was again observed. However, there was a general shift in distribution away from the area southeast of the Horns Rev 1 wind farm to areas west and particularly north of the wind farm, into areas where very few Common Scoters had previ-

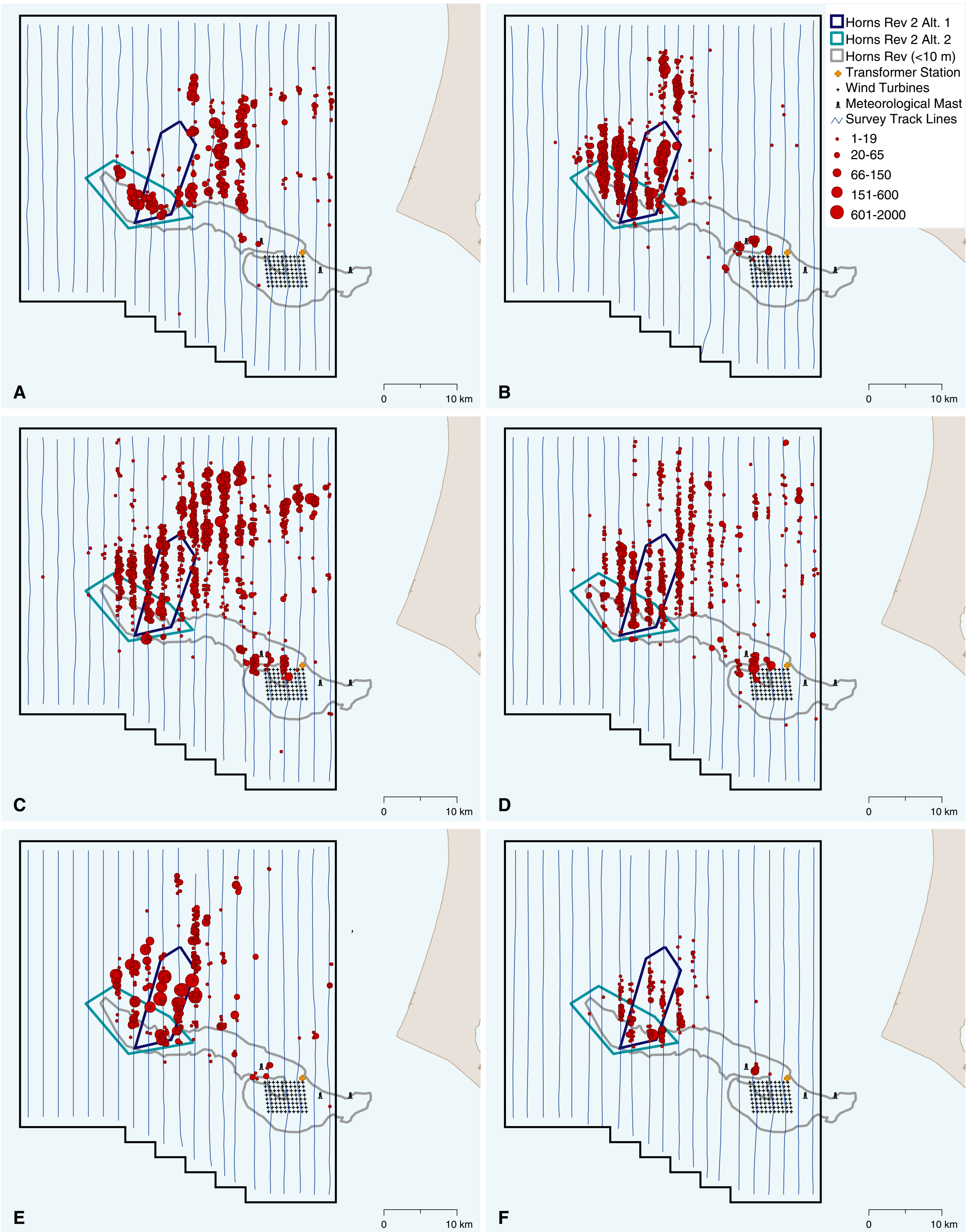

Figure 9. Numbers and distribution of Common Scoter in the Horns Rev 2 study area during each of six aerial surveys, 18 and 19 November 2005 (a), 2 February 2006 (b), 25 February 2006 (c), 12 March 2006 (d), 15 April 2006 (e) and 11 May 2006 (f). The flown track line of each survey is shown. The 10 m depth contour around Horns Rev is indicated and the Horns Rev 1 wind turbines, transformer station and meteorological masts are shown.

ously been observed (Petersen et al. 2004). During the surveys performed in 2004 this general pattern was maintained, with only few birds in the area southeast of the Horns Rev 1 wind farm and with a concentration of birds around the north-western corner of the Horns Rev 1 wind farm. During surveys in both 2004 and 2005 concentrations of Common Scoters were recorded out to the westernmost extension of the study area, and almost exclusively north of the reef (Petersen et al. in print). A thorough description of this change was reported to Energi E2 in a note dated 22 March 2006.

The reasons for this change in distribution are difficult to explain. In order to examine the food choice for the species at Horns Rev NERI applied for (and was granted) permission to collect Common Scoters at Horns Rev from the Danish Forest and Nature Agency. This led to the collection of a total of 26 Common Scoters in the area west and northwest of the Horns Rev 1 wind farm on 9 March 2005. Examinations of the stomach contents of the Common Scoters showed that they feed almost exclusively on American Razor Clam *Ensis americanus* in this area (unpubl. data). It is assumed that American Razor Clam had newly colonised the reef, and that this could be the explanation why so few Common Scoters were recorded upon the reef itself during the initial years of these investigations, but there is very limited data available about the distribution and abundance of razor clams on the reef in the literature. The bivalve community at Horns Rev reflects the extreme instability of the substrate and is neither rich in species diversity or biomass (Bio/Consult A/S 2005b).

The results of the investigation of stomach contents of Common Scoters did not allow for any quantitative description of food intake, nor did it give clear evidence of prey size choice. In only two cases were complete clams found in the oesophagus of the collected Common Scoters, and when clams were found to have entered into the gizzard, the shells were typically finely crushed. These finely fragmented parts could only be assigned into coarsely grained shell size classes. Based on this evidence, shells of the size class 6 to 9 cm clams predominated the food remains in the Common Scoters (Freudendahl & Jensen 2006). Regrettably there are no data available on the availability of different size classes of American Razor Clam present in the sediment of the reef. Bio/Consult found the species at the reef (reference Bio/Consult A/S 2005b), but the sampling method employed was not suitable for sampling razor clams, because this bivalve is capable of penetrating deep into the sediment by burrowing at very great speed. Thus it is unclear whether the 6 to 9 cm size class are the only size classes present at the reef or if Common Scoters specifically select for this particular size class because larger or smaller shells are less profitable (because of handling time or energetic cost/benefits). It is assumed that American Razor Clam will remain part of the infauna at Horns Rev, with temporal changes in distribution pattern of specific size classes, as the species tend to occur in clusters of relatively even size classes (Freudendahl & Jensen 2006). The temporal changes in razor clam distribution will potentially affect the local distribution of the Common Scoters, as the birds will favour areas with razor clams of a suitable size class and density.

The Common Scoters were found in especially high numbers in the area of the proposed Horns Rev 2 wind farm during the six ornithological surveys from November 2005 till May 2006. Calculation of the selectivity indices for these areas and for areas including a 2 and 4 km zone around them, showed high selection for the area of the proposed Horns Rev 2 wind farm site, with 25% of the Common Scoters recorded on 3.24% of the survey effort. This gave rise to a D-value of +0.82. Including the 2 and 4 km zones around the proposed site gave D-values of +0.80 and +0.84 (Table 3). The corresponding values for the alternative area of the wind farm were +0.74, +0.67 and +0.69 respectively for the wind farm site and including the 2 and 4 km zones (Table 4). If calculated on the basis of the number of clusters (flocks) rather than number of individuals the corresponding D-values for the proposed wind farm was 0.73, 0.76 and 0.78 respectively for the wind farm, the wind farm and 2 km zone around it and the wind farm and a 4 km zone around it. Likewise the D-values calculated on the basis of clusters for the alternative, southern position of the wind farm was 0.71, 0.63 and 0.60 respectively.

Common Scoters in the Horns Rev 2 study area showed a clear depth preference for 6 and 14 metres (Figure 10). 30% of the recorded Common Scoters were found in the depth interval from 10 to 12 m, and 90% of the birds were found in depths between 6 and 16 metres. This is strikingly different from the result of a corresponding calculation for Common Scoter depth frequency distribution in the Horns Rev 1 study area, where 82% of the observed birds were recorded in depths between 4 and 10 metres (Petersen et al. in print). It may be speculated that the available food resource, American Razor Clam, was such a highly profitable food resource that it was energetically favourable to dive deeper for this particular food item, compared to other traditionally exploited species elsewhere in the general area.

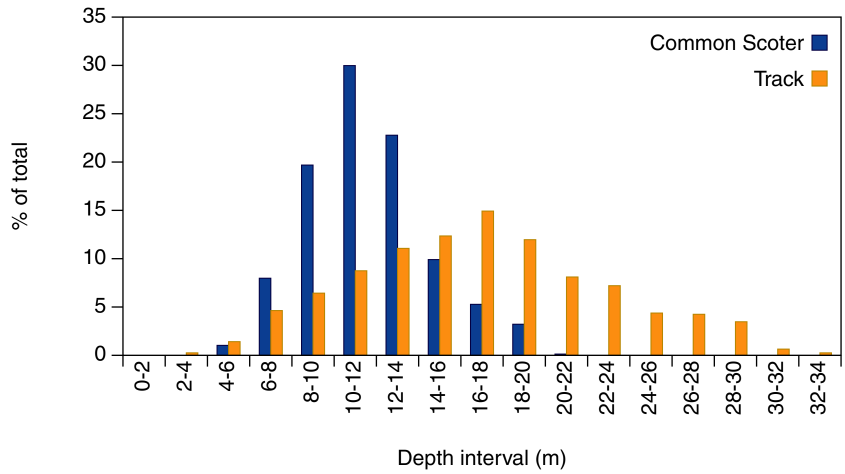

Figure 10. Water depth frequency distribution, in 2 m depth intervals, of 88,810 Common Scoters in the Horns Rev 2 study area during six aerial surveys performed between November 2005 and May 2006, compared to the corresponding frequency distribution of the survey track line.

In two cases during these aerial surveys were Common Scoters recorded within the Horns Rev 1 wind farm. On 25 February 2006, 324 birds were recorded in the northern parts of the wind farm, while on 12 March 2006, 61 Common Scoters were recorded in the north-western parts of the wind farm. These observations could potentially mark the start of a habituation response by Common Scoters towards the turbines, but the numbers involved make up only 1.5 and 0.5% of the encountered number of common scoters during the two surveys. It is therefore far too early to conclude that Common Scoter will show habituation to the wind turbines.

Using spatial modelling techniques to analyse the baseline aerial survey data covering the Horns Rev 2 areas, the total number and the spatial distribution of this species was modelled, survey by survey. The maximum modelled abundance of Common Scoters occurred on 2 February, when 93,596 birds were estimated present in the entire study site. Least Common Scoters were estimated in the May 2006 survey, with a total of 9,397 birds (Table 5).

Table 3. Percentage of birds (number of individuals) encountered in the Horns Rev 2 wind farm area (MA) based on six aerial surveys, as compared to the entire survey area, and in wind farm area plus zones of 2 and 4 km radius from the wind farm site (MA+2 and MA+4). Also shown are the total numbers of birds for each species/species group recorded throughout the surveys from the total study area (N). For each species and area, the Jacobs Index value (D) is given which varies between -1 (complete avoidance) and 1 (complete selection). The last column for each species category and area is the probability that these encounter rates differs from those of the entire area, based on one sample χ^2-tests. Values (P) are probabilities using standard statistical notation, n.s. represents P > 0.05, * P<0.05, ** P<0.01, *** P<0.001.

Species	MA	D for MA+0	P	MA+2	D for MA+2	P	MA+4	D for MA+4	P	N
Diver sp.	2,45	-0,14	n.s.	5,99	-0,15	n.s.	12,93	-0,05	n.s.	735
Gannet	1,09	-0,51	n.s.	9,78	0,12	n.s.	14,13	0,00	n.s.	92
Common Scoter	25,14	0,82	***	43,83	0,80	***	64,72	0,84	***	88810
Herring Gull	3,13	-0,02	n.s.	10,82	0,17	***	14,99	0,03	n.s.	1821
Little Gull	1,89	-0,27	n.s.	2,84	-0,49	***	10,40	-0,17	*	423
Kittiwake	2,11	-0,22	n.s.	7,75	-0,01	n.s.	23,24	0,29	**	142
Tern sp.	0,00	-1,00	***	3,25	-0,44	***	10,52	-0,17	*	523
Razorbill/Guillemot	1,34	-0,42	**	2,27	-0,57	***	5,48	-0,48	***	748
% of total survey coverage	3,24			7,92			14,15			

The bathymetric data seemed to contain some obvious inaccuracies, especially in areas south-east of the wind farm sites, leading to slightly unconventional density predictions for some parts of the area. This is not believed to have had any overall significant influence on the estimations of the total numbers of birds in the study area and no effect on the densities within the two proposed development areas. However, it proved impossible to incorporate depth as an explanatory covariate in the modelling estimations using the data from 2 February and from 11 May, and it may well be that the error in the depth data contributed to the necessity to drop this parameter from the final models employed to estimate birds densities on these dates.

The modelled spatial distribution of these numbers are presented in 500 by 500 m grid cells for each of the six surveys (Figure 11 a-f).

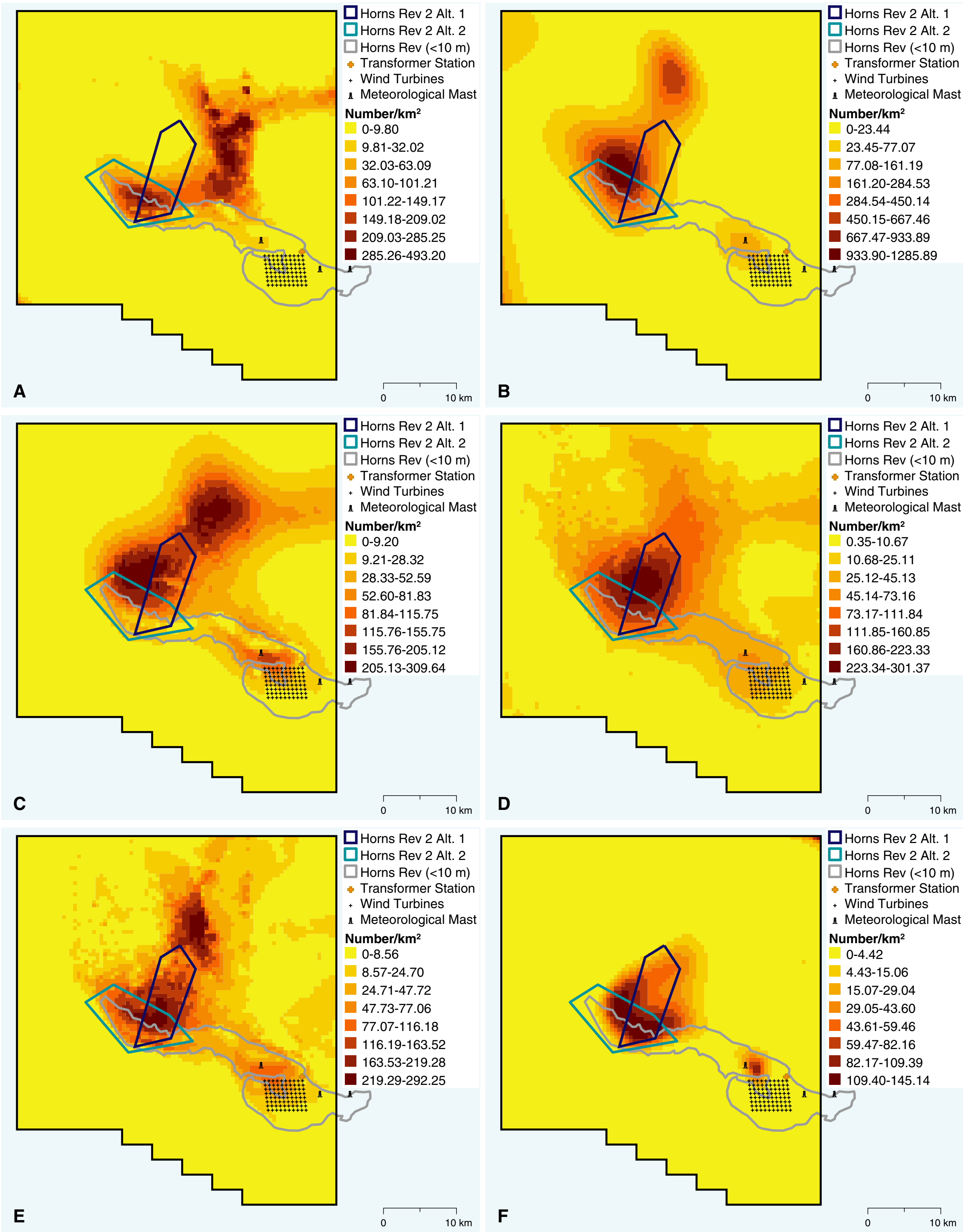

Figure 11. The modelled spatial distribution of 33,596 Common Scoters at Horns Rev on 18 and 19 November 2005 (a), of 93,848 Common Scoters on 2 February 2006 (b), of 47,867 Common Scoters on 25 February 2006 (c), of 48,898 Common Scoters on 12 March 2006 (d), of 38,542 Common Scoters on 15 April 2006 (e) and of 9,397 Common Scoters on 11 May 2006 (f). For details on the modelling background see text, but note that b and f are modelled without the use of depth as a covariate.

If it is hypothetically assumed that Common Scoters will be excluded from the wind farm site and the closest vicinity of 200-300 m, with a gradual reduced effect out to a distance of 2 km, and at the same time omitting the effect of a possible future habituation, the number of potentially displaced Common Scoters can be calculated, survey by survey, and for both the area of the proposed Horns Rev 2 wind farm and the alternative site. The maximum number of potentially displaced Common Scoters from the proposed Horns Rev 2 wind farm site was 29,135 birds, while 37,133 birds for the alternative site (Table 6). The lowest number of birds displaced using this hypothetical scenario was in May, when 6,172 Common Scoters would be affected. These calculations were made using the net area for the proposed Horns Rev 2 wind farm and the alternative situation, and it should be remembered that the actual area of a future wind farm will cover maximally 64% of the proposed northern wind farm area and 54% of the southern, alternative site.

Table 4. Percentage of birds (number of individuals) encountered in the alternative, southern Horns Rev 2 wind farm area (MA) based on six aerial surveys, as compared to the entire survey area, and in wind farm area plus zones of 2 and 4 km radius from the wind farm site (MA+2 and MA+4). Also shown are the total numbers of birds for each species/species group recorded throughout the surveys from the total study area (N). For each species and area, the Jacobs Index value (D) is given which varies between -1 (complete avoidance) and 1 (complete selection). The last column for each species category and area is the probability that these encounter rates differs from those of the entire area, based on one sample χ^2-tests. Values (P) are probabilities using standard statistical notation, n.s. represents P > 0.05, * P<0.05, ** P<0.01, *** P<0.001.

Species	MA	D for MA+0	P	MA+2	D for MA+2	P	MA+4	D for MA+4	P	N
Diver sp.	1,77	-0,38	*	3,13	-0,50	***	6,12	-0,46	***	735
Gannet	0,00	-1,00	n.s.	3,26	-0,48	n.s.	9,78	-0,24	n.s.	92
Common Scoter	20,77	0,74	***	32,79	0,67	***	48,83	0,69	***	88810
Herring Gull	4,12	0,04	n.s.	8,51	-0,01	n.s.	10,98	-0,18	***	1821
Little Gull	2,13	-0,29	n.s.	8,51	-0,01	n.s.	14,89	0,00	n.s.	423
Kittiwake	5,63	0,20	n.s.	17,61	0,38	***	27,46	0,36	***	142
Tern sp.	1,34	-0,49	**	11,09	0,13	n.s.	18,93	0,14	*	523
Razorbill/Guillemot	0,94	-0,62	***	2,94	-0,52	***	5,48	-0,50	***	748
% of total survey coverage	3,83			8,75			14,98			

The spatial interpretations of these potential displacements are illustrated for the proposed wind farm site (Figure 12 a-f) and for the alternative wind farm site (Figure 13 a-f) for each of the six surveys results.

Table 5. The estimated abundance of Common Scoter in the Horns Rev 2 study site based on six aerial surveys between November 2005 and May 2006. The covariates used for the spatial modelling are given, as well as the % deviance explained by these covariates.

Date	Abundance	Covariates used	Deviance explained
18./19. November 2005	33,596	Geo X,Y and depth	55.6%
2. February 2006	93,848	Geo X and Y	63.7%
25. February 2006	47,867	Geo X,Y and depth	51.5%
12. March 2006	48,898	Geo X,Y and depth	39.4%
15. April 2006	38,542	Geo X,Y and depth	41.0%
11. May 2006	9,397	Geo X and Y	65.9%

Table 6. The calculated number of displaced Common Scoters in and around the proposed Horns Rev 2 wind farm site and the alternative site, presented for each of the six aerial surveys performed. The reduction is based on a hypothetical exclusion from the wind farm site and the nearest 200-300 meters and with a gradual reduced effect out to a distance of 2 km.

Date	No. of potentially displaced birds from wind farm site	No. of potentially displaced birds from alternative wind farm site
18./19. November 2005	6646	8168
2. February 2006	29135	37133
25. February 2006	11825	8086
12. March 2006	15887	11893
15. April 2006	13015	10455
11. May 2006	6172	5262

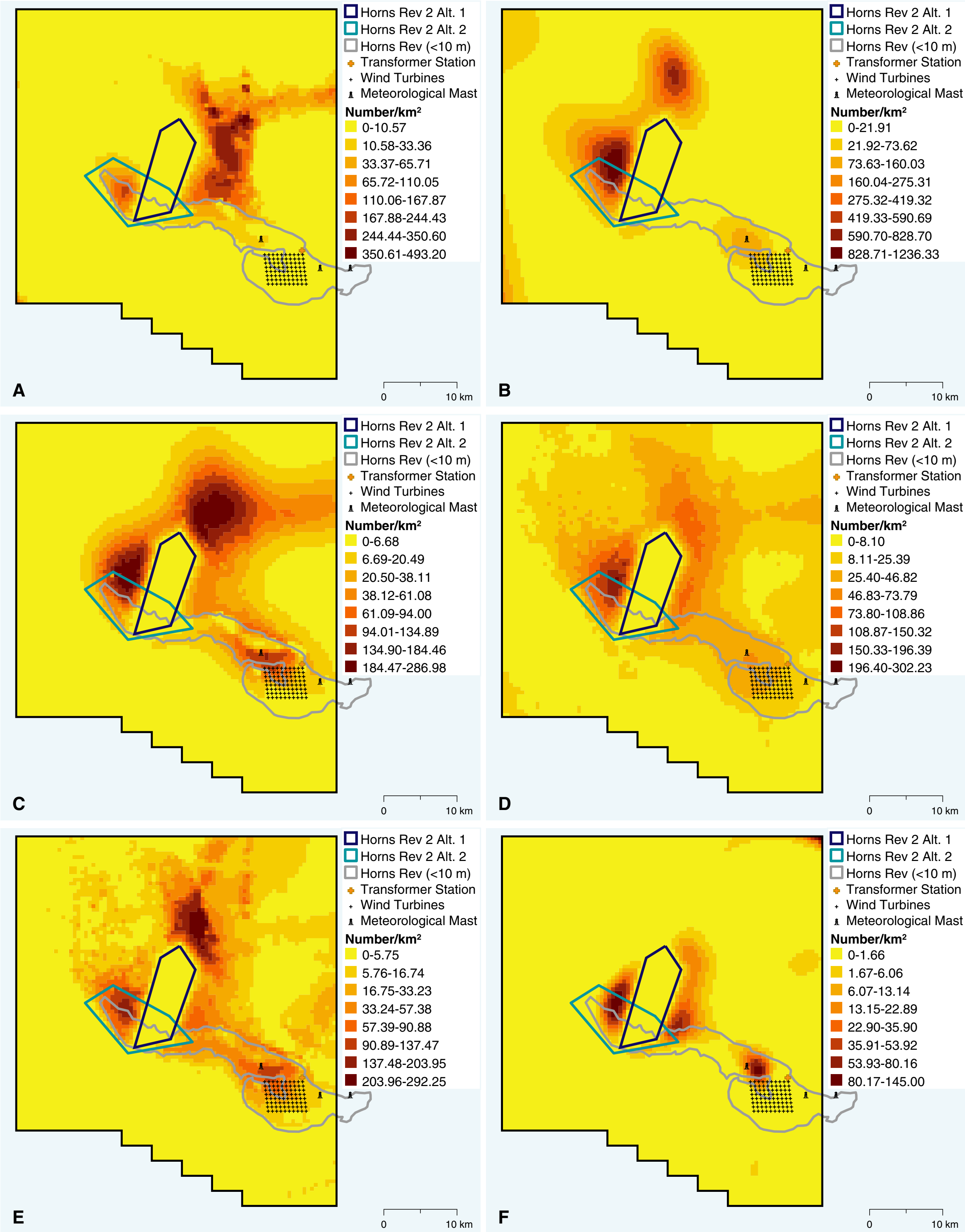

Figure 12. The modelled displacement of Common Scoters from the proposed Horns Rev 2 wind farm, assuming total exclusion from the wind farm site and a graduate reduced effect out to a distance of 2 km from the site for each of the six survey scenarios (a to f). For details on the modelling background see text, but note that b and f are modelled without the use of depth as a covariate.

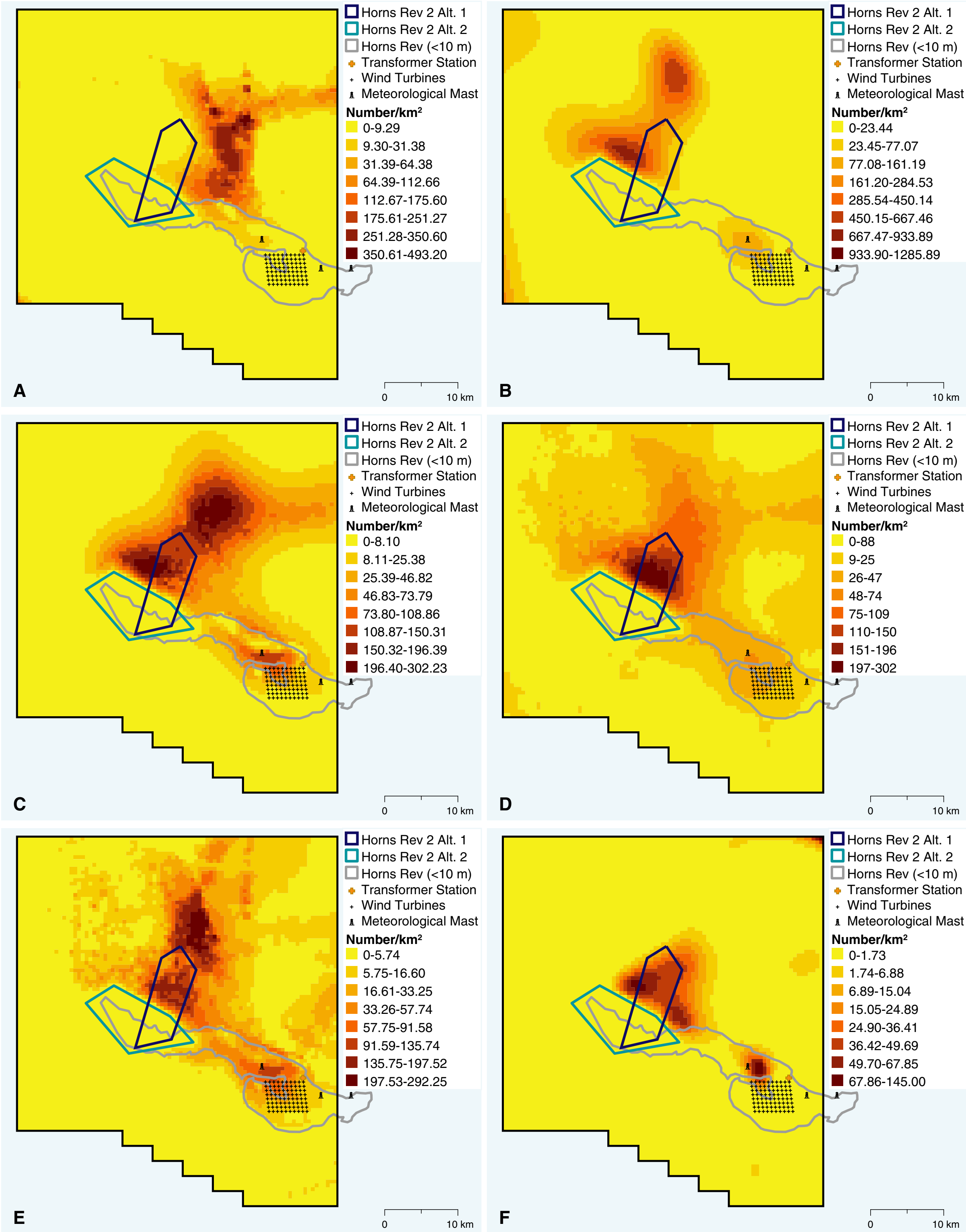

Figure 13. The modelled displacement of Common Scoters from the alternative, southern Horns Rev 2 wind farm site, assuming total exclusion from the wind farm site and a graduate reduced effect out to a distance of 2 km from the site for each of the six survey scenarios (a to f). For details on the modelling background see text, but note that b and f are modelled without the use of depth as a covariate.

Herring Gull

A total of 1,821 Herring Gulls were recorded during the six aerial surveys of birds from November 2005 till May 2006. Highest numbers were recorded on 2 February (566) and 15 April (519), but few birds in May (Table 2).

Herring Gulls were most abundant in the eastern and central parts of the study area (Figure 14), but the distribution varied considerable between surveys (Figure 15 a-e). In November 2005 birds were found scattered across the eastern parts of the study area, while almost no birds were recorded in the western parts. On 2 February and on 15 April Herring Gulls concentrated in the area north of the Horns Rev 1 wind farm and on 25 February and 12 March birds were observed scattered in the central parts of the survey area.

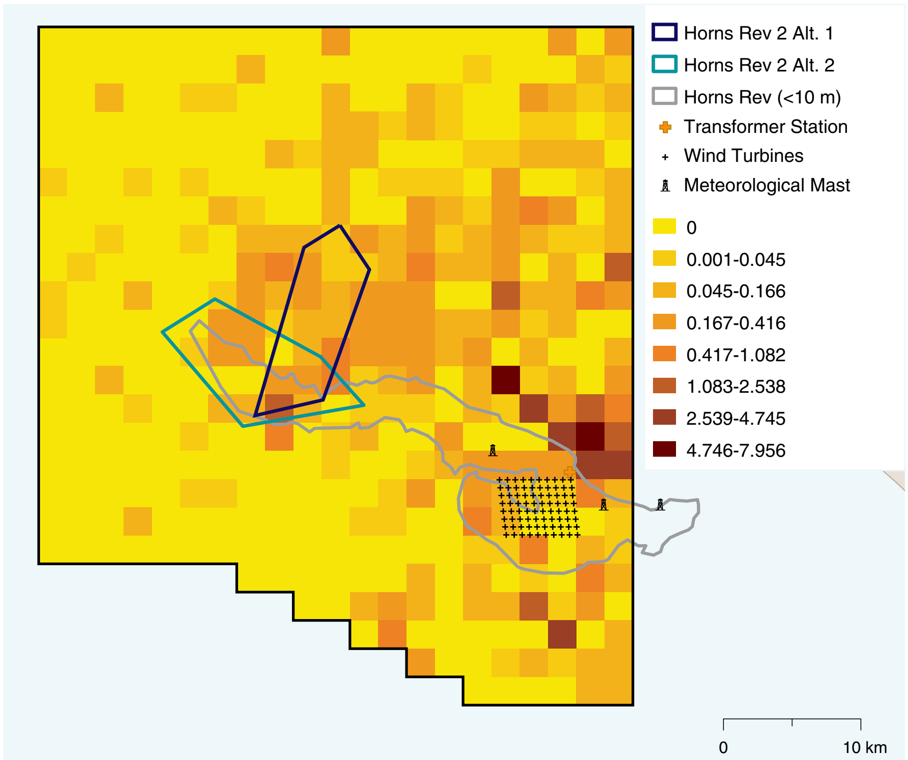

Figure 14. Relative density of Herring Gull in the Horns Rev 2 study area, based on six surveys performed between November 2005 and May 2006. Data expressed as number of observed birds per kilometre of flown transect coverage in each 2 x 2 km grid square.

When calculating the selectivity index for Herring Gull on the basis of these data, the proposed wind farm site and the alternative site did not differ from the general survey area, and thus these areas were neither selected for or avoided (Tables 3 and 4), with D-values of -0.02, +0.17 and +0.03 respectively for the three zones around the proposed wind farm site and +0.04, -0.01 and -0.18 for the alternative wind farm site.

Results from investigations of birds in connection with the Horns Rev 1 wind farm showed that Herring Gulls were much more abundant in the coastal zone, east of the study area for this project (Petersen et al. in print).

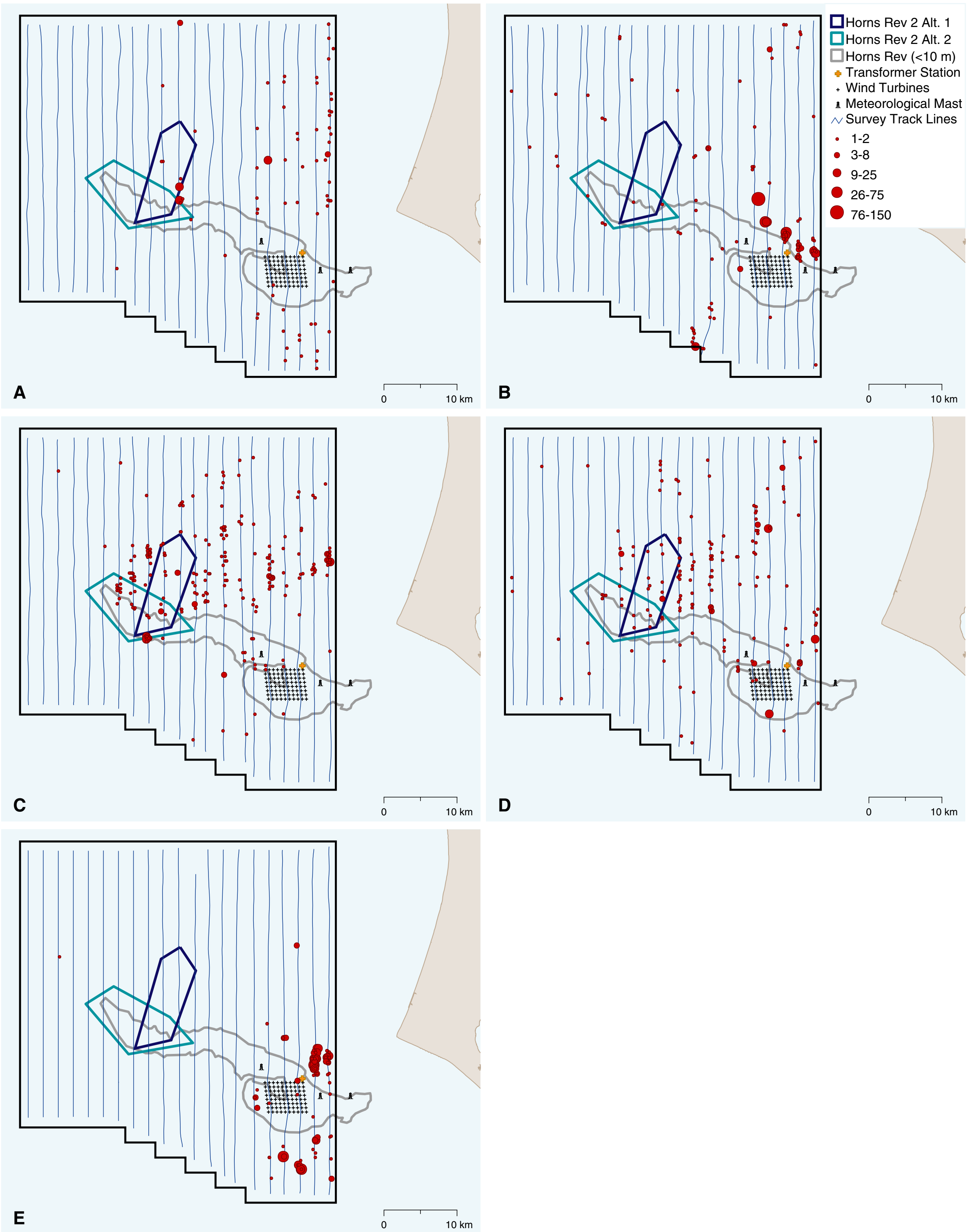

Figure 15. Numbers and distribution of Herring Gull in the Horns Rev 2 study area during each of five aerial surveys, 18 and 19 November 2005 (a), 2 February 2006 (b), 25 February 2006 (c), 12 March 2006 (d) and 15 April 2006 (e). The flown track line of each survey is shown. The 10 m depth contour around Horns Rev is indicated and the Horns Rev 1 wind turbines, transformer station and meteorological masts are shown.

Little Gull

A total of 423 Little Gulls were recorded during the six aerial surveys between November 2005 and May 2006. Far most birds were recorded on 15 April 2006 (266), but the species was recorded during all surveys (Table 2).

Little Gulls were most abundant in the eastern parts of the study area, particularly north and east of the Horns Rev 1 wind farm (Figure 16). This distribution pattern was also seen during a survey in November 2005 (Figure 17 a), and in April 2006, when there were scattered observations of the species in the western parts of the study area (Figure 17 b). These findings are not in accordance with the results from surveys made in connection with the Horns Rev 1 wind farm site, where highest densities of little gulls were found in the area west and northwest of that wind farm, including the area of the proposed Horns Rev 2 wind farm site (Petersen et al. in print). The difference between the two sets of results is probably linked to the fact that the present results consist of data dominated by one survey in April 2006.

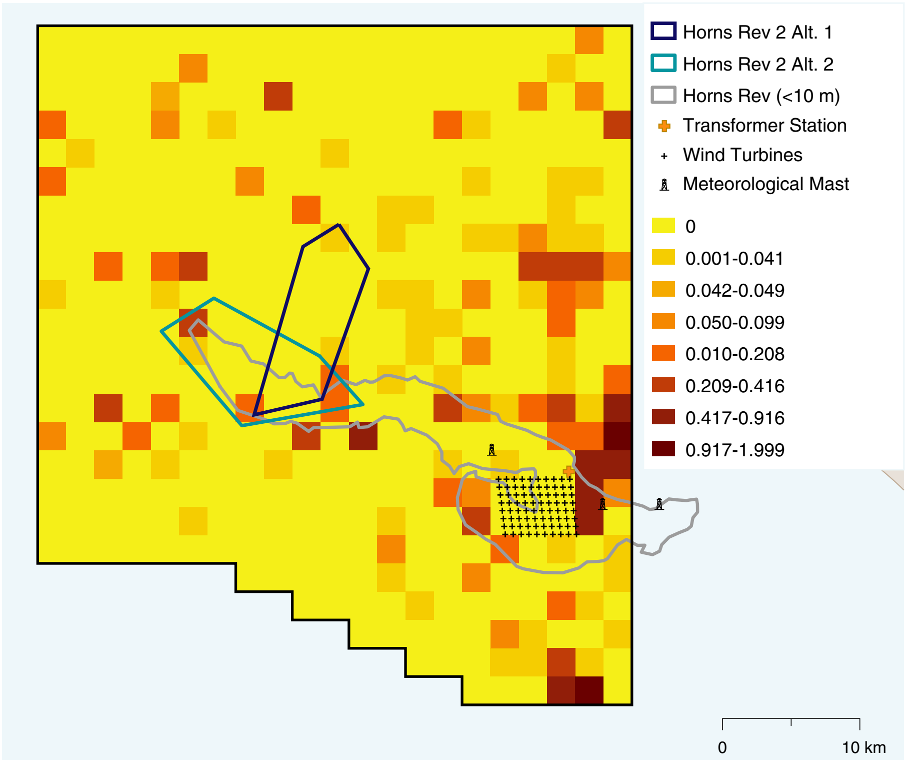

Figure 16. Relative density of Little Gull in the Horns Rev 2 study area, based on six surveys performed between November 2005 and May 2006. Data expressed as number of observed birds per kilometre of flown transect coverage in each 2 x 2 km grid square.

When calculating the selectivity index for Little Gull on the basis of these six surveys it showed that the species avoided the proposed wind farm site, with D-values of -0.27, -0.49 and -0.17 respectively for the wind farm site and the 2 and 4 km zones around it, with significant levels of avoidance only found when including the 2 and 4 km zones (Table 3). The picture was different for the alternative Horns

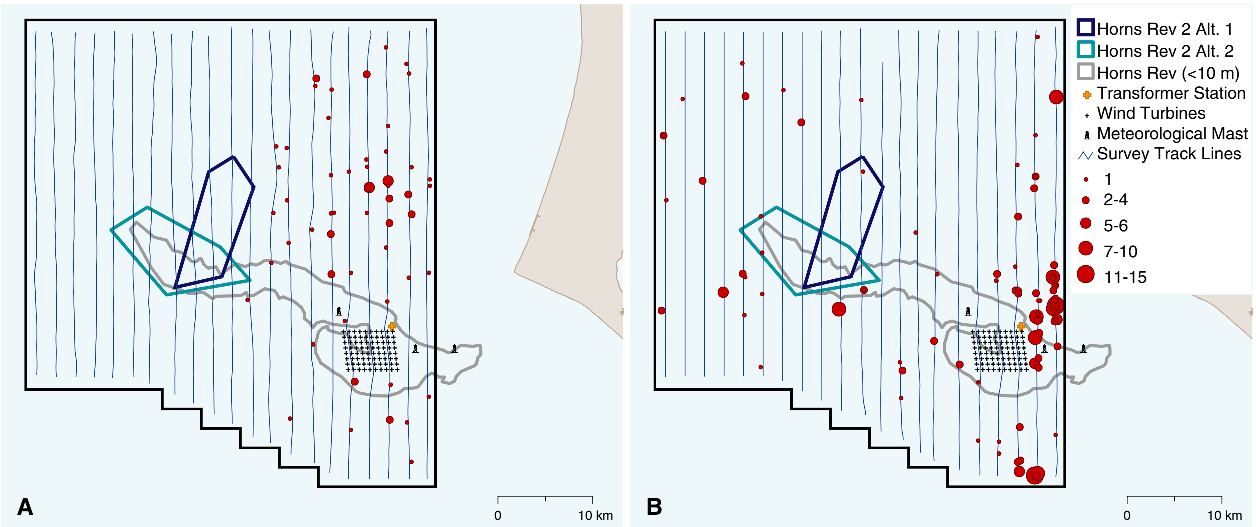

Figure 17. Numbers and distribution of Little Gull in the Horns Rev 2 study area during two aerial surveys, 18 and 19 November 2005 (a) and 15 April 2006 (b). The flown track line of each survey is shown. The 10 m depth contour around Horns Rev is indicated and the Horns Rev 1 wind turbines, transformer station and meteorological masts are shown.

Rev 2 site, where selectivity indices of -0.29, -0.01 and 0.00 were found for this site, indicating a non-significant avoidance of the alternative site, while utilising the area including a 2 and 4 km zone around it to almost exactly the same degree as the general study area (Table 6).

Kittiwake

A total of 142 Kittiwakes were recorded during the six aerial surveys performed between November 2005 and May 2006. Most birds were recorded in November 2005 (89), but with records of this species from all surveys (Table 2).

Kittiwakes were recorded in the central northern and southern parts of the study area during a survey in November 2005 (Figure 18).

The selectivity index for Kittiwake based on the six surveys showed avoidance of the proposed wind farm site, with a D-value of -0.22. When including the 2 km zone the selectivity index was -0.01, while it became positive, with a D-value of +0.29 when including the 4 km zone (Table 3). The picture was different for the alternative Horns Rev 2 site, where selectivity indices of +0.20, +0.38 and +0.36 were found for this site, indicating slight selection for the alternative site (Table 4).

Kittiwakes were most abundant at Horns Rev in autumn (Petersen et al. in print).

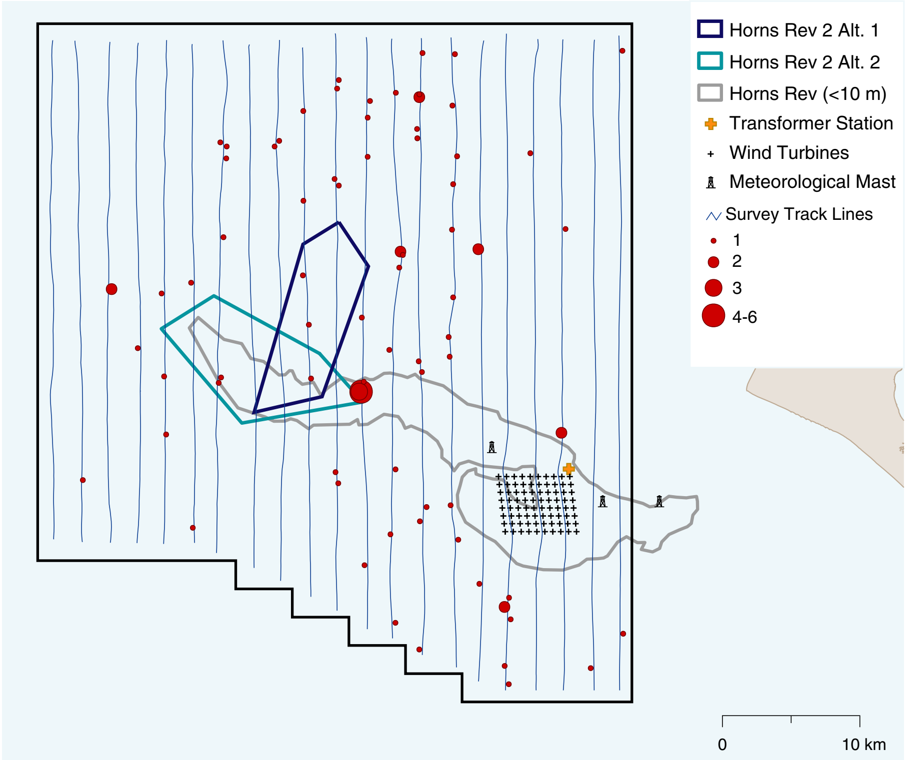

Figure 18. Numbers and distribution of Kittiwake in the Horns Rev 2 study area during an aerial survey on 18 and 19 November 2005. The flown track line of the survey is shown. The 10 m depth contour around Horns Rev is indicated and the Horns Rev 1 wind turbines, transformer station and meteorological masts are shown.

Terns

Data on all terns combined are presented here, merging data involving 301 Arctic/Common Terns, 68 Sandwich Terns and 154 unidentified terns from the six aerial surveys between November 2005 and May 2006 (Table 2). The majority of the terns were observed in April (120) and May (403) of 2006.

Terns were most abundant in the western part of the study area, off the western point of Horns Rev (Figure 19). This was also the case on 11 May 2006 (Figure 20 a), while the birds were more scattered during a survey in April 2006. On this occation a concentration of terns were recorded shortly south of the area of the proposed Horns Rev 2 wind farm, on the southern drop of the reef (Figure 20 b).

A calculation of selectivity indices for terns showed that they significantly avoided the area of the proposed Horns Rev 2 wind farm, also when including the 2 and 4 km zones around it. Selectivity indices were -1.00, -0.44 and -0.17 respectively for the three distance zones (Table 3). Likewise there was a significant avoidance of the alternative Horns Rev 2 site, but a moderate selection for that area when including the 2 and 4 km zones, with selectivity indices of +0.13 and +0.14 for the two zones (Table 4).

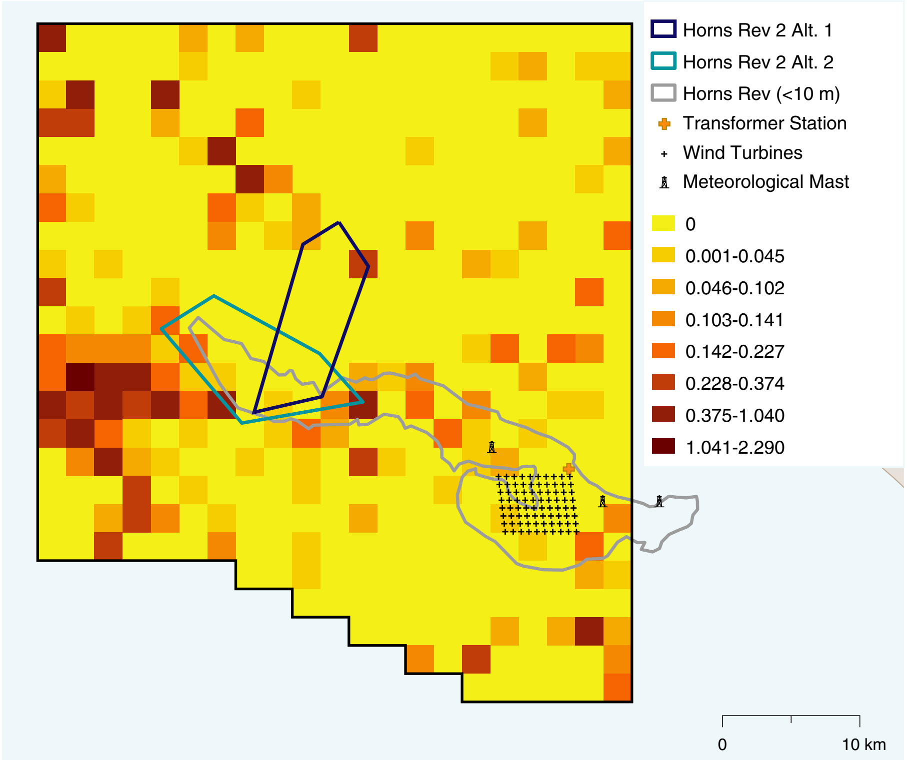

Figure 19. Relative density of Arctic, Common and Sandwich Terns in the Horns Rev 2 study area, based on six surveys performed between November 2005 and May 2006. Data expressed as number of observed birds per kilometre of flown transect coverage in each 2 x 2 km grid square.

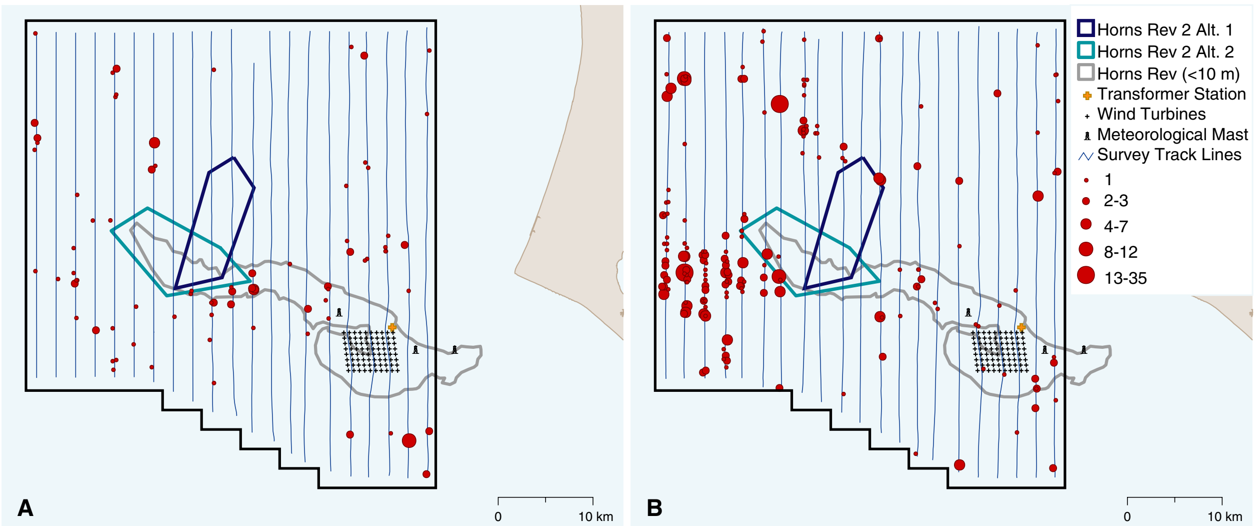

Figure 20. Numbers and distribution of arctic, common and sandwich terns in the Horns Rev 2 study area during two aerial surveys, 15 April 2006 (a) and 11 May 2006 (b). The flown track line of each survey is shown. The 10 m depth contour around Horns Rev is indicated and the Horns Rev 1 wind turbines, transformer station and meteorological masts are shown.

Razorbill/Guillemot

A total of 748 Razorbills/Guillemots were recorded during the six aerial surveys between November 2005 and May 2006. Of these, by far the majority of the birds (in total 578) were observed during the survey in November 2005 (Table 2). The majority of these birds (91%) were unidentified Razorbill/Guillemot, while 7% were identified as Razorbills and 2% as Guillemots.

Razorbills/Guillemots were most abundant in the north-eastern and south-eastern parts of the study area (Figure 21). This distribution pattern was strongly dominated by the result of the November 2005 survey (Figure 22), as 77% of all birds were recorded during this particular survey. This is probably also why there is little similarity in distribution patterns between results from this study and the results from the surveys performed in connection with the Horns Rev 1 wind farm, where Razorbills/Guillemots were most abundant in the south-western and north-western areas of the study area relevant for that study (Petersen et al. in print).

Selectivity indices for Razorbills/Guillemots showed that they significantly avoided both the area of the proposed Horns Rev 2 wind farm and the alternative wind farm site. Selectivity indices for the proposed wind farm site were -0.42, -0.57 and –0.48 respectively for the wind farm site and when including the 2 and 4 km zones around it (Table 3). The corresponding values for the alternative, southern wind farm site were -0.62, -0.52 and -0.50, indicating a higher degree of avoidance here than for the northern wind farm site (Table 4).

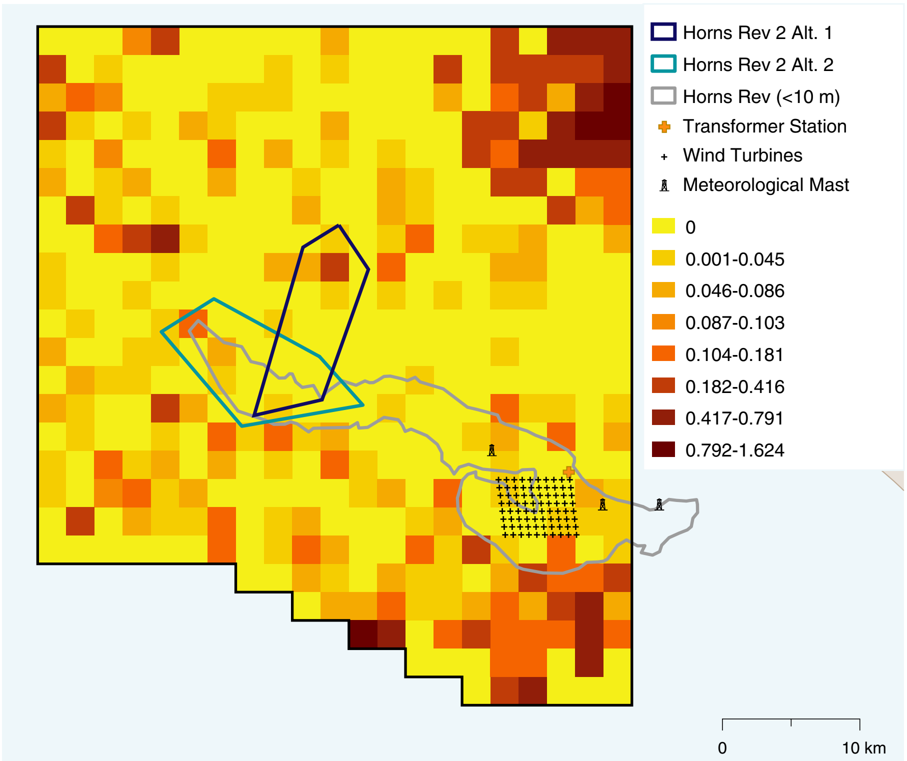

Figure 21. Relative density of Razorbill/Guillemot in the Horns Rev 2 study area, based on six surveys performed between November 2005 and May 2006. Data expressed as number of observed birds per kilometre of flown transect coverage in each 2 x 2 km grid square.

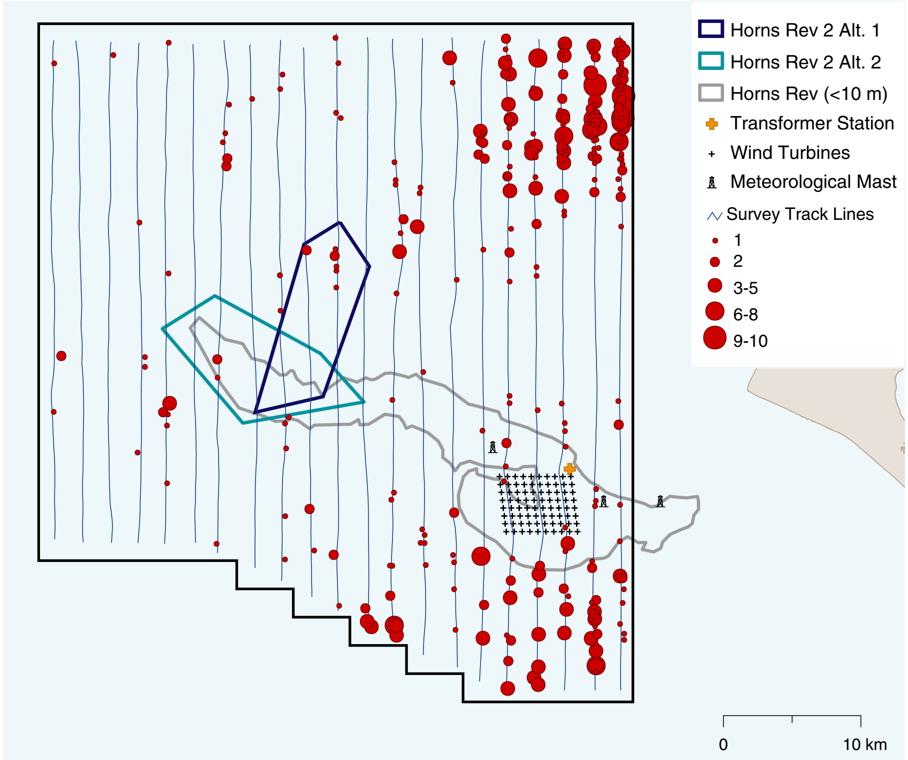

Figure 22. Numbers and distribution of Razorbill/Guillemot in the Horns Rev 2 study area during an aerial survey on 18 and 19 November 2005. The flown track line of each survey is shown. The 10 m depth contour around Horns Rev is indicated and the Horns Rev 1 wind turbines, transformer station and meteorological masts are shown.

4 Impact assessment

4.1 Potential impacts of offshore wind farms on birds

The potential impacts on birds from the operating Horns Rev 2 wind farm are predicted to fall under three main headings:

1. Physical change of the habitat where the turbines are erected.
2. Disturbance/avoidance effects.
3. Collision risk.

Given that the Horns Rev 2 wind farm is the second wind farm to be erected in the same area, a potential impact from the combined presence of two such large wind farms has to be considered in the impact assessment for the Horns Rev 2 wind farm, even though this is located c. 14 km west of the Horns Rev 1 wind farm.

As an example, the presence of two wind farms may potentially act as a barrier to migrating birds, so that, in a worst case scenario, migrating birds will not pass on between the open area between the two wind farms. Likewise, the presence of two wind farms may cause birds to modify their flight patterns to avoid the vicinity of the wind farms, which would affect the potential risk of collisions between birds and wind turbines.

In general, impacts on birds related to disturbance effects caused by the wind farm are expected during both construction and during operation phases. Disturbance effects related to the period of construction are of temporary duration and hence predicted to be of low impact if mitigating measures are taken. It is therefore expected that impacts, which may have implications for birds, will largely relate to the period when the turbines are operating. Assessments of disturbance effects to birds were consequently focused on impacts expected to occur in the period when the wind farm is in operation.

4.1.1 Physical change of habitat

The presence of 95 wind turbines in an offshore area may affect birds in several ways. Firstly, the turbines will reduce the available area by their physical presence. Secondly, the foundations of the turbines may create a new type of sublittoral habitat that may provide additional substrate for invertebrates and other prey that birds can potentially feed on. Thirdly, the turbines may serve as platforms for resting and perching birds, thereby attracting birds to the area that would not exploit it previously.

Foundations of 95 conventional turbines and 3 experimental turbines in the Horns Rev 2 wind farm, are expected to physically cover an area of less than 0.5 ha, including a zone with added scour protection. Compared to the total area of 3,500 ha in which the turbines area placed, the foundations will only cover a very limited area with a concurrent small proportional loss of bottom fauna. Therefore, the habitat loss is expected to be negligible to birds.

The addition of boulder for scour protection of the turbine foundations in a zone of approximately 20-25 m around the turbines will have the potential to act as artificial reefs that would attract various marine organisms which are suitable as prey for birds. The experiences obtained during studies at the Horns Rev 1 wind farm, showed that settlements of Balanoids and Blue Mussels *Mytilus edulis* takes place on the turbine foundations, but that heavy predation from the sea star *Asterias rubens* reduces these populations markedly and inhibits permanent or expanding colonisation (Bio/Consult A/S 2005a). Likewise the scour protection provides a habitat for several fish species, including the dominant Ballan Wrasse *Labrus bergylta* (Berggylt), Goldsinny-wrasse *Ctenolabrus rupestris* (Havkarusse), Sandeel *Hyperoplus sp.* (Tobis), Goby *Gobius sp.* (Kutling), and Schooling Cods *Gadus morhua* (Torsk) (Bio/Consult A/S 2005a).

Given the short distance between the two wind farms, the succession of benthic invertebrates and fish communities at the Horns Rev 2 wind farm is expected to be comparable to that which was recorded at Horns Rev 1. Likewise the attraction by these food resources to birds is also expected to be comparable to what was recorded at Horns Rev 1.

The presence of mussels on the foundations of turbines in the Horns Rev 1 wind farm, did not elicit any observable bird attraction of either mussel specialists or other benthic feeding diving birds. Of specialised mussel-eating birds, the Eider was the only species recorded during the studies at Horns Rev 1, but the number observed at the wind farm site was extremely low and Eiders were never observed foraging around turbines. Much higher numbers of Eiders were found in the coastal areas, reflecting that the distribution of Eiders was confined to more shallow waters (cf. Petersen et al. in print). Common Scoter was recorded in high numbers close to the Horns Rev 1 wind farm, but stomach analyses showed that the diet of Common Scoter was dominated by the American Razor Clam, a species specifically associated with the sandy seabed characteristic for the general Horns Rev area. Of fish-eating birds, only Cormorants were observed regularly at the Horns Rev 1 wind farm. Cormorants were observed making foraging dives around wind turbines and the birds also used the platforms on the turbines towers (c. 8 m above sea level) for resting. However, as the number of Cormorants recorded at the Horns Rev 1 wind farm was relatively low, the presence of Cormorants may reflect the possibility of using the turbines as resting platforms and not an increased presence of exploitable fish stocks. No other fish-eating bird species, e.g., terns, were found to show preference for the near-turbines areas, indicating an attraction from increased food resources associated with the turbine structures (cf. Petersen et al. in print).

At the Horns Rev 1 wind farm, the number of bird species recorded to use the turbines as resting or perching platforms was low, mainly including Cormorants and large gull species. In general the number of records of resting or perching birds was very low, suggesting that the turbines were not attractive resting or perching platforms to birds. This interpretation was supported by observations of resting/perching birds mostly were made on turbines located at the edge and not inside the wind farm, and on turbines that were not operating (cf. Petersen et al. in print).

Based on present knowledge, the physical changes imposed by constructing the Horns Rev 2 wind farm are assessed to have very limited, if any, impacts on birds in the area. Specifically, no impact is expected in relation to 'habitat loss' as a result of the physical presence of 98 turbines because of the very little area that is actually affected. Secondly, the combination of the effective predation of colonial benthic invertebrates by sea stars and the far offshore location would probably not attract normally shallow-diving flocking species to the wind farm area. Thirdly, since a comparable list of species is expected to occur at Horns Rev 2 than at Horns Rev 1, the lack of attraction of fish-eating bird species recorded at Horns Rev 1 is expected to account for the Horns Rev 2 wind farm as well.

The presence of the turbines may attract certain seabird species, like gulls and cormorants, which may use the platforms offered by the turbines as perches. In addition, some of the bird species migrating over the area (see chapter 3), may under certain conditions - particularly situations with low visibility (haze or fog) - use the turbines for roosting. Diurnally migrating species such as Starlings S*turnus vulgaris*, may be attracted to the turbines. White flashing light for ship navigation (visible at distances of minimum 3 nautical miles) will be mounted on the turbines at a height of c. 10 m above water level. For species which migrate at night, these lights may prove attractive, especially drawing tired and disoriented individuals during periods of poor visibility.

4.1.2 Disturbance effects

Even if the wind farm does not result in a substantial impact on the food resources used by waterbirds in the immediate vicinity *per se*, the turbines may themselves have an impact through the (largely visual) disturbance they cause to birds that stimulates an avoidance response amongst birds. Such a response is thought to be an instinctive response to unfamiliar objects, especially moving objects, and is widely reported in the literature. The basis for this response is matter of conjecture, but it is highly likely that the reticence of birds to approach unfamiliar animated objects could represent their behavioural response to a perceived quasi-predation risk. In this way, the presence of turbines may limit accessibility to food or some other resource (such as a safe overnight resting place) within the wind farm area to which they formerly had access. Whether or not such an effect is permanent, or temporary (i.e. that as birds get used to unfamiliar objects, so the response moderates) also has consequences for the assessment of this impact. Clearly if birds can become used to the presence of turbines, the effects on the population are far less than if the effect is permanent.

The first study undertaken involving waterfowl/seabirds and their reactions to turbines at sea was that concerning Eider at Tunø Knob in the Kattegat, and that showed barely demonstrable impacts. However, the study concentrated upon a single species, the Eider, which is considered relatively robust to disturbance. Moreover, the study involved a wind farm consisting of only 10 turbines in two rows (Guillemette et al. 1999). The more recent studies at Horns Rev 1 and Nysted have demonstrated clearly that the avoidance effects shown by waterbirds are highly species specific (Petersen et al. in print). The studies at Horns Rev 1 are especially relevant, since the combined radar and visual observations showed that some species were almost never witnessed flying between turbines despite their abundance outside (e.g. divers and Gannets), others rarely did so (e.g. scoters) or generally avoided flying far into the wind farm (e.g. terns), whilst others (e.g. Cormorant and Gulls, especially Greater Black-backed and Herring Gulls) showed no sign of avoidance at all (Petersen et al. in print). The aerial survey data also clearly showed that divers at Horns Rev 1 showed almost complete avoidance of the wind farm post construction, despite being present in average densities prior to construction. In this case, despite the apparent seriousness of the problem at the ecological level, the numbers of birds involved were small and therefore were very unlikely to have an effect on the population level. The interpretation of the use by Common Scoter of the Horns Rev 1 wind farm area was difficult, because of the birds' absence in the vicinity during the baseline, compared with very large numbers post construction (Petersen et al. in print). The extreme scarcity of visual observations of scoters flying in between turbines and the lack of observations during aerial surveys post construction (when up to 381,000 birds were present in the general area) confirm that this was also amongst the species that showed almost complete avoidance of flying or swimming between the rows of turbines, despite very large concentrations in the surrounding waters. This finding has considerable consequences for the interpretation of the potential effect of the Horn Rev 2 on this species. Long-tailed Ducks showed statistically significant reductions in density post construction in the Nysted wind farm (and in sectors 2 km outside) where they had shown higher than average densities prior to construction. This strongly suggests major displacement of this species from formerly favoured feeding areas, although again in this case, the absolute numbers were relatively small and therefore of no significance to the population overall. Terns and Auks were almost never counted in the Horns Rev wind farm post construction, but were present in densities similar to the overall average prior to turbine erection, but because of high variance during the baseline, the differences were not statistically significant. Comparing pre-construction distributions of birds with sufficient sample sizes with those post construction, no bird species convincingly demonstrated enhanced use of the waters within the two Danish offshore wind farms after the erection of turbines, but it was clear, for example amongst Cormorants at Nysted, the wind farm area was used occasionally for social feeding by very large numbers of birds post construction.

In order to assess the magnitude of such potential effects on birds using the vicinity of the Horns Rev 2 wind farm, we calculated:

1. The percentage of birds within the wind farm area in relation to percentage of birds in the total investigated area,

2. The same relationship under the assumption that some species may show avoidance behaviour towards the turbines up to a distance of 2 km,
3. As 2., but assuming an avoidance distance of 4 km
4. Estimated total numbers and spatial distribution using spatial modelling techniques in order to access the potential magnitude of displacement of Common Scoter.

As can be seen from the tables, for all the waterbird species involved, the percentage of the total numbers of birds in the surveyed area that fell within the boundaries of the two potential development areas was less than 5% for all but Kittiwake and Common Scoter (see Table 5 and 6). With the exception of common scoter, most species avoided or showed no preference for the potential development areas and occurred in absolute numbers that fell a very long way short of international importance. Hence in terms of the general avoidance of the wind farm shown by the waterbird species that occur in the area, with the exception of Common Scoter, most species will not suffer any major displacement effect by the construction of the wind farm. This is either (i) because (as in the case of gulls) they show little sign of displacement at Horns Rev 1 and are therefore unlikely to show such responses at Horns Rev 2 or (ii) because those species that do show strong avoidance effects (e.g. divers) are present in such relative and absolute low densities as to represent an insignificant effect locally and on the population as a whole.

However, the situation for Common Scoter is more serious. This species occurs in estimated numbers within the two potential development areas in numbers that exceed international importance (i.e. >16,000 individuals). Such high numbers and densities are unusual anywhere within the normal core range of the species and under guidelines for site safeguard (e.g. under Ramsar Convention and Birds Directive), this recognises these areas of potentially high importance to the population as a whole. Because there were no Common Scoters present along Horns Rev during the baseline preconstruction studies of Petersen et al. (in print), they were unable to conclude firmly that Common Scoters were displaced from within the Horns Rev 1 wind farm. However, they firmly concluded that the species "...showed almost complete avoidance of flying or swimming between rows of turbines, despite very large concentrations in the surrounding waters". It is fair to conclude that this effect is just as likely to be the case with the proposed Horns Rev 2 site. Hence, if the food resource and conditions that support the current concentrations out along Horns Rev and in surrounding waters persist, it seems reasonable to model the potential impacts of the wind farm construction based on the total displacement scenarios provided in the species account for Common Scoter above. This strongly suggests that the proposed development areas both support, on average, c. 33% of estimated total number of Common Scoter in the survey area, that neither is particular favorable than the other (e.g. because of substantially less potential displacement) and that construction at either site would cause the potential displacement of between 6100 and 29000 (proposed wind farm site) and between 5200 and 37000 (alternative wind farm site) under the conditions prevailing during the current baseline studies, and reiterating the calculation were made for the net areas of the proposed wind farms and excluding the effect of a possible future habituation.

4.1.3 Collision risk

Collisions with wind turbines will act as an added source of mortality to bird popualtions. This means that the potential impact of mortality through collision will vary depending to some extent on the population dynamics of the species as outlined in section 1.4. Species with a high reproductive output and a correspondingly low annual survival rate will be less sensitive to additional mortality than species with a high annual survival rate and a low reproductive output.

With specific reference to the Horns Rev 2 offshore wind farm, collisions are predicted to potentially occur in relation to:

- Annual migration of birds between breeding areas and winter quarters,
- Daily flights of birds between e.g. roosting sites and foraging areas,
- Active foraging flights,
- Birds flushed due to disturbance (e.g. turbine maintenance activities),
- Birds attracted to the wind farm area during migration.

A common factor, critical in assessing the risk of collisions, is flight altitude. Bird species that fly at altitudes that correspond to the area swept by turbine rotors are expected to be at a higher risk than those that fly either above or below the rotors. At the moment, there is no decision made as to the specifications of the dimension of the turbines to be erected at Horns Rev 2, but for the turbines in the Horns Rev 1 wind farm, the cross-sectional area of collision risk (i.e. the area swept by turbine rotors) in a row of 8 turbines constitutes 7% to 9% of the total cross sectional area from sea level to the highest position of the rotors at the edge of the wind farm. Thus the probability that a flying bird passes the risk zone of the rotors will be less than 10%, assuming that no avoidance behaviours are taken and that birds are randomly distributed at all altitudes.

At present, the actual collision risk for the critical species occurring at Horns Rev cannot be assessed, since this also depend on the probability that a bird or bird flock flying through the risk zone actually will be hit by the rotor, which in turn, critically depends on factors such as bird size, wind speed (rotor speed), the birds flying speed and angle of bird passage. Such species specific data does not exist for those relatively few species that occur with high frequency in the vicinity of the proposed wind farm.

The risk of Eiders colliding with wind turbines when passing the Nysted offshore wind farm (72 turbines) was estimated to involve between 40-50 individuals out of a total annual migration volume of 260,000 birds passing during autumn migration, when corrected for the number of birds that showed flight deflection and passed around the wind farm (Petersen et al. in print).

Only one study has, to our knowledge, documented a collision between waterbirds and offshore wind turbines. This case involved a flock of 310 migrating Eiders, which was hit by turbine rotors, resulting in four birds falling to the sea surface. Of these, three individuals took off again, and one Eider was apparently fatally injured (Pettersson 2005). Pettersson (2005) estimated that of the c. 100,000 waterfowl in spring and 800,000 in autumn, the frequency of collision would approximate one per turbine per year.

The height of the turbines to be erected at Horns Rev 2 is presently unknown, but they will most probably by somewhat larger than the turbines in the Horns Rev 1 wind farm. Likewise the three experimental turbines may reach an altitude of 200 m to the top of the rotor, probably resulting in a further elevation and expansion of the potential collision area swept by the rotors for such large turbines.

Generally, the flight altitudes of birds vary significantly between species. Some species fly at low altitudes, others at higher. Weather influences the altitude and generally, flight altitude is greater in tailwinds than in headwinds (Alerstam 1990, Krüger & Garthe 2001). Some species migrate during the day, others at night, and some both during the day and night and this too may influence flight altitude. Flight altitude may also be related to their activity at the time. Thus, for most species, the range of flight altitudes is large and for these there is a potential risk of collision if they fly in the same level as that of the turbine rotor. Some sea bird species, however, are so closely associated with the sea surface that they only occasionally fly at altitudes where they are at risk of colliding with the rotor.

Measurements of the vertical distribution of birds by radar at the Horns Rev 1 wind farm showed that most bird migration (30-40%) took place evenly distributed in altitudes from sea level to 200 m, and that there was no obvious difference in flying altitudes between bird migration during daytime and during night time (Blew et al. 2006). However, at the Nysted wind farm, there was a marked difference showing bird migration at much higher altitudes during night time than during daytime, which may related to a more substantial nocturnal migration of passerine birds in this area (Blew et al. 2006). This was also confirmed by the lack of migrating birds flying at night between the turbines at altitudes below 120 metres using infra-red TADS systems (Petersen et al. in print).

Species of birds that are expected to occur at critical altitudes on migration in the Horns Rev area are divers, Gannet, Common Scoter, Cormorant, waders, terns and gulls. Of these, Cormorant and dabbling ducks are not normally associated with substantial offshore migration, and will probably not occur in the turbine area in high numbers, as was documented by the studies at Horns Rev 1 (Petersen et al. in print). Substantial wader migration was, however, observed in spring at Horns Rev 1, but this migration occurred at altitudes of c. 400 metres, high above the turbines. Observations from Horns Rev 1 verified that Common Scoter and terns generally flew at altitudes below those of the turbine rotors, and only very rarely occurred at higher altitudes. A similar pattern was evident for most gull species, especially smaller gulls, whereas larger gulls, Herring Gull and Great

Black-backed Gull, were more frequently recorded flying in rotor altitudes at Horns Rev 1 (Petersen et al. in print).

The general pattern of bird migration at the Horns Rev 1 offshore wind farm showed that most birds approaching the wind farm deflected at some distance to the wind farm, resulting in at most c. 15-30% of the total volume of birds entering the wind farm. In addition, those birds that flew into the wind farm most often passed through the area midway between the turbine rows, or in several situations were recorded to leave the wind farm area by the shortest possible way. Since migrating birds entered the wind farm perpendicular to the outer row both when approaching the wind farm from the north and from the east, this pattern can be interpreted as a response to minimise contact with the rotating turbines. Hence, the patterns of deflection and of flight paths passing through the wind farm recorded at the Horns Rev 1 wind farm suggest that the probability of birds colliding with the turbines is markedly reduced compared to a situation were such avoidance responses were not performed. Given the proximity of the two wind farm areas, it is expected that similar patterns of avoidance in migrating birds will occur in relation to a second operating wind farm at Horns Rev, and consequently that the Horns Rev 2 wind farm will represent a correspondingly low mortality risk to birds.

4.1.4 Cumulative impacts from two adjacent offshore wind farms

Following construction of the Horns Rev 2 offshore wind farm, two large wind farms of 80 and 95 turbines, respectively, will be present in the area separated by a distance of approximately 14 km. If these two wind farms in combination have impacts on migrating birds passing through the Horns Rev area, these are assessed to be related to a barrier effect that potentially will affect the birds by

1. increasing migration distance
2. increasing the risk of collision.

Likewise, to species that avoid exploiting the wind farm areas, the presence of the Horns Rev 2 wind farm may reduce the total area available to foraging and loafing that corresponds to

3. habitat loss.

In relation to the two former categories the potential impacts depend on birds showing avoidance that can be attributed to the presence of two wind farms. Thus, one critical factor will be whether migrating birds pass through the 14 km opening between the wind farms or avoid this area and deflect around the wind farms either turning west passing around Horns Rev 2 or east passing around Horns Rev 1. Alternatively, the birds may also perform turns or fly in circles of varying number before passing through the opening between the wind farms. Depending on the proximity of these movements to the wind farms, the birds may potentially be at risk of colliding with the turbines.

Given the patterns of deflection documented by the studies at both Horns Rev 1 and at Nysted with many birds of most species recorded relatively close (< 1 km) to turbines at the edge of the farms when passing around these, and flying down equidistance between the turbine rows once within the park, a 14 km gap between the wind farms at Horns Rev probably offers sufficient open space for migrating birds to pass the area. However, the studies at Horns Rev 1 have documented that the deflection away from the wind farm could take place at distances of up to 4-5 km, implying that at least some birds or bird species make adjustments in flight orientation to this wind farm at very long distances. Thus, if birds that make deflections at great distances exhibit just slightly enhanced avoidance reactions as a result of the presence of two wind farms, the opening of 14 km between the wind farms may be avoided.

Should the Horns Rev 2 wind farm elicit such a barrier effect to bird movements in the area, the birds that show deflection will increase their flight distance, with implications for the energy budgets of the birds. For example, birds on migration need to refuel, replenishing energy stores at certain sites in order to successfully fuel further movements along the flyway. Equally, wintering birds are highly dependant on adequate but limited food resources to survive the winter period. Thus, in such situations, even slight increases in energy expenditure, may have implications for the birds to successfully survive the energy demanding periods of migration and winter.

For the bird species migrating through the Horns Rev area once or twice a year, the extra distance of making a local deflection of 2-20 km, will probably be insignificant when compared to their overall migration path of several hundred kilometres or more. Even if the birds make multiple turns to find a new path of passing the area, the increased distance will, to most species, be of little consequence.

Birds that exploit the area during extended staging or wintering periods and make daily movements between foraging and roosting areas may be more adversely affected in terms of increased energy expenditure if these movements are disrupted and extended by the presence of the wind farm. At Horns Rev 1, the Common Scoter and Gannet were species that avoided the wind farm area, but which were also present in the area for prolonged periods. These species are thus candidates for species which are susceptible to extended daily travel distance. However, both Common Scoter and Gannets were recorded in high numbers close to the operating Horns Rev 1 wind farm, suggesting that when the birds were situated outside the wind farm, the operating turbines did not present a disturbance stimulus to these species. Thus, excepting the possibility that the erection of the Horns Rev 2 wind farm would elicit a markedly enhanced avoidance reaction in these species (which will be readily observable), the potential for combined effects of the two wind farms to incur critically increased travel distances, and hence increased energy expenditure, in locally staging bird species at Horns Rev is considered to be negligible.

A potential increase in the risk of bird collisions could result from birds making multiple turns in the areas to the north or south of the wind farm before passing around the Horns Rev area or even passing through the wind farms. It is generally considered that this increased risk is minimal. Having said this, it is also acknowledged that even very small increases in mortality as a result of collisions in birds species characterised by low annual mortality rates may have marked negative implications for these species. However, at Horns Rev, the pattern of birds deflection recorded at the Horns Rev 1 wind farm showed that birds made the most marked corrections in flight orientation at distances of 400 m to 1,000 m from the turbines. This suggest that most, if not all species that potentially will undertake turns in response to the construction of the two wind farms in the area, should have ample space in which to make corrective flights, and thus, that the collision risk from the presence of to wind farms is not synergistically increased. The risk of collision associated with construction of the Horns Rev 2 wind farm is consequently expected to be of a similar low level to that assessed for the Horns Rev 1 wind farm, although these assessments are based on the pattern of deflection and not from actual collisions risk estimates. The flight patterns and avoidance reactions shown by birds towards the presence of two wind farms is presently unknown, so the collision risks presented by the two large wind farms could be assessed by a simple predictive model and amalgamated as the synergistic result of the sum of the effects of two wind farm combined.

Although it is tempting to conclude that the cumulative effects of collision mortality have the most fundamental impact on the population level, the cumulative effects of habitat loss should not be considered as trivial. For species with highly restricted marine habitat, habitat loss may have population level effects, because displaced birds have poorer quality or little alternative habitat to which to resort. In the report of Petersen et al. (in print) considering the first two large offshore marine wind farms ever constructed, they concluded that these effects are likely to be small, as the area affected compared to the extent of similar shallow waters was miniscule, and the numbers of birds (in both absolute and relative terms in relation to local densities and overall flyway numbers) were very small.

On the local scale the cumulative effect from the Horns Rev 1 and Horns Rev 2 is expected to be additive, but in case the lack of access to the Horns Rev 1 wind farm does increase densities of Common Scoters in the surrounding waters, the effect from a Horns Rev 2 wind farm could potentially be higher than would have been the case without a Horns Rev 1 wind farm.

In the flyway perspective the cumulative impacts of many more such developments distributed along the length of a species migratory corridor could have impacts on survival and reproduction in the future. This is especially the case where a single development is likely to displace a significant proportion of a flyway population from a single site, especially where the cumulative effects of multiple such developments may be substantial. It is certainly the case with the two alternative sites proposed in the present project, that both have been shown to affect an average of 30-35% of the Common Scoter using the general area in all seasons during the present survey baseline and where these numbers exceed 1% of the total flyway population. This latter statistic qualifies the area for designation as a Ramsar wetland of international importance and potentially as a European Union Special Protection Area, and means that if such numbers were displaced post-construction, there would be substantially greater habitat loss than has resulted from the Horns Rev 1 project, where it was not possible to demonstrate habitat loss for Common Scoter, because of the lack of birds in the baseline studies close to the wind farm area.

However, it is equally impossible to understand the full implications of habitat loss at the population level without knowledge of the full extent, availability and quality of habitat available to a population throughout its geographical range. The challenge of addressing cumulative impacts of this and other human developments on populations of birds is critical to the future development of offshore wind resources, but remains beyond the scope of the present EIA, and needs to be the subject of continuing future research.

4.1.5 The experimental turbines

The three experimental turbines planned to be part of the Horns Rev 2 wind farm, differ from the standard turbines in the wind farm by virtue of their height. With a maximum height of 200 m, these turbines will reach 70 m higher than the turbines in the Horns Rev 1 wind farm. Given the larger size of these turbines, the area of high collision risk swept by the rotors is probably proportionally greater than for standard turbines. However, as the actual size remains unknown, the exact area swept by the rotors can not be calculated at present.

As a consequence of a larger sweep area, the risk of bird collision with these large turbines is basically assessed to be higher than for the standard turbines. This assessment takes into account that the altitudinal distribution of bird migration recorded at Horns Rev 1 (Blew et al. 2006), showing that 30-40% of the birds recorded by radar is located in altitudes between sea level and 200 m. Likewise, it is also assumed that larger turbines generally will be located at farther distances from each other, thereby potentially offering a less massive obstacle to flying birds, that may result in less marked avoidance and hence a higher number of birds passing through a wind farm consisting of such large turbines.

At the Horns Rev 2 wind farm the three experimental turbines will probably not represent a dramatic increase in collision risk, as these three turbines will be part of a wind farm of smaller, but equally sized turbines which probably will be the stimulus that releases a deflection response in the majority of birds in this area. For this reason it is not expected that the larger size of three turbines will have a different effect on bird avoidance behaviour, and hence collision risk. Theoretically, if the three experimental turbines are located so that birds that show general deflection to the full wind farm are likely to come in close to these when passing around the wind farm, an increased risk of collision may exist.

5 Conclusions

The results of the baseline studies, combined with the recent experiences gained from the Horn Rev 1 project provide a far more robust basis for the environmental assessment process of the Horns Rev 2 proposals than could have ever been achieved prior to this time. We can therefore be more confident that the physical changes caused by the constructions of the turbines at either of the two alternative sites will have little effect on the waterbirds of the area. The extent of habitat change is trivial and the only species likely to be actively attracted to the development is the Cormorant. Based on the radar and visual studies at Horns Rev 1, it seems likely that although highly species specific, the dominant response of waterbirds to the proposed wind farm will be avoidance, such that many of the most abundant species in the area will avoid flying in close vicinity of turbines, and particularly will avoid entering between turbines within the park. This will reduce the probabilities of collision as observed elsewhere, but because we have insufficient specific data on flight trajectories in the area (especially altitude), it is currently not possible to model annual species specific collision rates as has been attempted for migrating Eider at Nysted. The negative side of such avoidance behaviour is the certain effective loss of habitat caused to particular species. Although divers are of high conservation interest and showed demonstrable avoidance of the Horns Rev 1 wind farm, their low level of abundance within the general area, and within the two proposed development areas specifically, mean that the effects of such displacement in future are minimal and highly unlikely to have any effect at the population level. In contrast, Common Scoter were present along Horns Rev in very high densities prior to and during the baseline studies and occurred in both proposed development areas at numbers exceeding international importance. This species shows strong indications of avoidance responses and therefore the loss of these areas as feeding and loafing areas is likely to be highly significant. No other species were present in numbers that would give cause for concern or they showed no displacement at other studied sites.

With regards to the cumulative effects of these proposals, it remains difficult to provide reliable predictions of such effects when so few wind farms of such size exist. Given that this is only the second wind farm constructed at Horns Rev, the physical areas of sea (and hence suitable habitat) involved remain very small and (with the notable exception of Common Scoter) the potential numbers of individual birds displaced remains very small, the cumulative effects are likely to be negligible for all species excepting Common Scoter. However, we have no information upon which to base an assessment of the cumulative effects of the visual barrier presented by the existence of two such wind farms in such proximity as to be visible to migrating birds simultaneously at some distance. Hence, although it would seem likely that the 14 km of open water between the existing Horns Rev 1 and proposed Horns Rev 2 wind farm is sufficient to channel migrating birds through the stretch of open water between them, we cannot rule out the possibility that birds will show a preference for migrating northwards or southwards around the outside of both. Under this eventuality, migration routes would be extended, but still to a degree unlikely to ever add more than 1-2% of the distance involved during a migration episode.

One drawback of the present assessments is related to the uncertainty over the precise location, the size, number and nature of the turbines. Consequently, some caution in drawing firm conclusions on the environmental impacts of the Horns Rev 2 wind farm, especially with respect to collisions risk that may be affected by the pattern of turbines in the area, should be taken. Likewise, the extraordinary high degree of inter-annual variation in bird distribution and abundance in offshore areas and the unknown relations between the occurrence of Common Scoter and the American Razor Clam and the dynamics of the later, posses some difficulties in judging the future occurrence of scoters at Horns Rev.

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Appendix 1. List of species names in Danish, English and Latin

Danish	English	Latin
Lom sp.	Diver sp.	Gavia sp.
Rødstrubet lom	Red-throated Diver	Gavia arctica
Sortstrubet lom	Black-throated Diver	Gavia stellata
Gråstrubet lappedykker	Red-necked Grebe	Podiceps griseigena
Mallemuk	Fulmar	Fulmarus glacialis
Sule	Gannet	Sula bassana
Skarv	Cormorant	Phalacrocorax carbo
Havlit	Long-tailed Duck	Clangula hyemalis
Ederfugl	Eider	Somateria mollissima
Sortand	Common Scoter	Melanitta nigra
Fløjlsand	Velvet Scoter	Melanitta fusca
Storkjove	Great Skua	Stercorarius skua
Almindelig kjove	Arctic Skua	Stercorarius parasiticus
Kjove sp.	Skua sp.	Stercorarius sp.
Sølvmåge	Herring Gull	Larus argentatus
Sildemåge	Lesser Black-backed Gull	Larus fuscus
Svartbag	Great Black-backed Gull	Larus marinus
Hættemåge	Black-headed Gull	Larus ridibundus
Dværgmåge	Little Gull	Larus minutus
Ride	Kittiwake	Rissa tridactyla
Måge sp.	Gull sp.	Larus sp.
Fjordterne	Common Tern	Sterna hirundo
Havterne	Arctic Tern	Sterna paradisaea
Hav/fjordterne	Arctic/Common Tern	Sterna paradisarea/hirundo
Splitterne	Sandwich Tern	Sterna sandvicensis
Alk	Razorbill	Alca torda
Alk/lomvie	Razorbill/Guillemot	Alca torda/Uria aalge
Lomvie	Guillemot	Uria aalge

Effects on birds of the Horns Rev 2 offshore wind farm:
Environmental Impact Assessment

National Environmental Research Institute
Ministry of the Environment