DONG energy

Horns Rev II Offshore Wind Farm Monitoring of Migrating Waterbirds

Baseline Studies 2007-08

DHI WATER • ENVIRONMENT • HEALTH

Orbicon

Client

DONG Energy A/S
Teglholmen
A.C. Meyers Vænge 9
DK 2450 København SV
Tel: +45 4480 6000

Representative
Lars Bie Jensen
E-mail labie@dongenergy.dk

Consultant

Orbicon A/S
Jens Juuls Vej 18
DK 8260 Viby J
Tel: +45 8738 6166

DHI Water Environment Health A/S
Agern Allé 5
DK-2970 Hørsholm
Tel: +45 4516 9200

In association with:
BIOLA
Gotenstrasse 4
D - 20097 Hamburg
Tel: + 49 40 2380 8791

Marine Observers
Svankjærvej 6
DK-7752 Snedsted
Tel: +45 9796 2696

Authors

Werner Piper
Gerd Kulik
Jan Durinck
Henrik Skov
Simon B. Leonhard

Project	132-07.1004
Project manager	Simon B. Leonhard
Quality assurance	Simon B. Leonhard
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Approved	Lars Sloth
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Database: Cynthia Erb, Gerd Kulik, Werner Piper

GIS: Ellen Heinsch, Jan Durinck,

Observers: Werner Piper, Lutz von der Heyde, Dr. Hans-Wolfgang Nehls, Karsten Kohls, Hans Pelny, Thilo Christophersen

Photos: Jan Durinck, Thomas W. Johansen, Henrik Skov, Jens Christensen

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1 SUMMARY

DONG Energy has commissioned a consortium of Orbicon and DHI in association with BIOLA to undertake a study of bird migration as part of the monitoring program for the planned Horns Rev 2 offshore wind farm. This report contains the results of the baseline phase running from October 2007 to April 2008. With respect to bird migration the monitoring program is focused on documenting the long-distance migration across and along Horns Rev during autumn and spring. This information is needed in order to describe any impacts of the construction of Horns Rev 2 offshore wind farm on migratory birds and to describe any cumulative effects, here especially potential barrier effects as a consequence of both the Horns Rev 1 and Horns Rev 2 wind farms. The potential barrier effects on feeding movements of birds staging in the area is given less attention. The statistical design of the monitoring program is based on the BACI approach applied to radar recordings (direction and density of echoes), and it incorporates data from the PSO monitoring programme for the Horns Rev 1 wind farm (HR1).

The establishment of the Horns Rev 2 offshore wind farm (HR2 OWF) was granted by the Department of Energy on the 19th March 2007 on the basis of DONG Energy's application of 13th October 2006. The location of the HR2 OWF is planned for the outer part of Horns Rev, and it consists of a total of 91 turbines, each 2.3 MW which are placed with 13 east-west oriented rows of 7 turbines. The monitoring of bird migration was based on combined visual and radar studies. Due to the late start of construction works at the HR2 OWF only the spring period was covered, and no platforms were available for mounting the radar at the site. Hence, the study had to be made from an anchored vessel at HR1 and HR2 in combination with visual observations and a fixed installation at Blåvands Huk. Two X-band ship surveillance radars with a power output of 12 kW and 25 kW, respectively, were used for the radar observations. They were both operated with the antenna rotating horizontally. The two radar devices in use were a Decca "BridgeMaster E" at Blåvands Huk and a Furuno "FR 2105" on the vessel.

Post-processing was made with the purpose to compare bird movements observed at the two anchoring positions at the HR1 and HR2 OWF's as well as to compare the results of bird migration/movements at Horns Rev with those at Blåvands Huk in terms of timing, intensity, direction, flight altitude and species composition. Radar images of the horizontal radar were captured from the screen signal via video splitter by a framegrabber card on a PC using custom-made software called SWARM (by TriOS Mess- und Datentechnik, Oldenburg). One screenshot was stored every minute and a cumulative picture every 5 minutes. All radar recordings were transferred to a GIS database allowing the analyses of flight directions and patterns of tracked trajectories. At each location, flight intensities were estimated both as effort-corrected totals for all birds recorded and for selected species groups (visual observations). In addition, to demonstrate the apparent concentration of bird movements and migration near the coast during the study period flight intensities were estimated in relation to distance from the coast at Blåvands Huk. An analysis of flight intensities with distance was made using radar data from Blåvands Huk and summarising flight intensities in 15 north-souths oriented transects, each with a width of 1 km, extending from the coast to the Horns Rev 1 offshore wind farm.

At both offshore sites movements of birds were dominated by ducks, terns and gulls with Common Scoter, Herring Gull, Lesser Black-backed Gull, Common Gull and Sandwich Tern being numerically the most important species. As these species groups usually were stationary for longer periods and certain individuals were likely to be present in the area for the duration of several hours or even days, more than 80 % of the observations in both study areas might represent foraging flights or flights of resting birds. Divers were observed more frequently at HR2, and Common Scoters less frequently as compared to HR1. The vast majority of the observations at Blåvands Huk were of typical coastal water birds, whereas no songbirds were seen. The three most abundant species at Blåvands Huk were Common Scoter (57.6 %), Divers (15.6 %) and Knots (4.7 %).

As a result of the dominance of scoters, terns and gulls the altitudinal distribution of flights displayed a concentration at altitudes lower than 20 m. At Blåvands Huk, due to the migration of geese, a moderate proportion of birds were observed at altitudes between 40 and 200 m.

The study revealed low flight intensity over Horns Rev and hardly any migration activity during daylight hours – most birds being local displaying feeding movements in all directions. Between HR1 OWF and Blåvands Huk profile analyses showed a steep increase in flight intensities approaching the coast at Blåvand. In general, flight intensities were much higher both for migration and feeding movements near the coast than offshore. The movements of birds at Blåvands Huk were dominated by southward movements of waterbirds compensating for northward drift by the current during the night.

The bird migration study indicated that movements driven by local and in most cases moderate feeding concentrations are more important on Horns Rev in spring, while close to Blåvand compensating movements of Common Scoters are more important. This is corroborated by the baseline monitoring of resting birds in the area showing a concentration of Common Scoters west of Blåvands Huk and only few birds feeding over Horns Rev. No response behaviour to HR1 OWF could be established due to the low flight intensity at the site and lack of feeding concentrations of Common Scoter. In addition, the use of ship-based radar shortened the effective detection range limiting the scope for tracking behavioural changes of birds passing the wind farm.

The low intensity of bird movements and migration during spring indicate that potential barrier effects of the two wind farms on long-distance migrants most likely are of limited magnitude during this season. However, the profile analyses of the radar data from Blåvand indicate that larger movements of Common Scoters occur irregularly offshore, and the aerial surveys over the past five years have shown that a larger proportion of the scoters in the area may concentrate over the western part of the reef, especially during late winter. It should be noted that the potential barrier effects on long-distance migrants may be larger during autumn migration due to the much higher volume of birds passing through the area during autumn as compared to during spring.

As the data on bird migration collected during the PSO programme did not cover the central and western areas of Horns Rev the cumulative database on bird migration across Horns Rev is judged insufficient for the baseline of the HR2 monitoring programme. For this reason the baseline has been extended into the autumn season 2008 using the established foundations in the HR2 OWF as platforms for continuous re-

cordings using 25 kW radars concurrently with recordings from the HR1 transformer station and from the coast at Blåvands Huk.

DANSK RESUME

Et konsortium bestående af Orbicon og DHI i samarbejde med BIOLA har på vegne af DONG Energy gennemført en undersøgelse af fugletrækket ved Horns Rev som en del af overvågningsprogrammet for den planlagte Horns Rev 2 havvindmøllepark. Denne rapport indeholder resultaterne af baseline, som blev gennemført mellem oktober 2007 og maj 2008. Med hensyn til fugletræk er overvågningsprogrammet fokuseret på at dokumentere langdistancetrækket på tværs af og langs med Horns Rev om foråret og efteråret. Denne information er nødvendig for at beskrive mulige effekter af anlægget af Horns Rev 2 vindmølleparken på trækkende fugle og for at beskrive eventuelle kumulative effekter, herunder specielt barriereeffekter som følger af både Horns Rev 1 og Horns Rev 2 vindmølleparkerne. Den potentielle barriereeffekt på fourageringsbevægelser i området er i denne sammenhæng prioriteret lavere. Det statistiske design for overvågningsprogrammet er et BACI-design, baseret på sammenligninger af radarobservationer (retning og tæthed af ekkoer), og programmet inkluderer data fra PSO-overvågningsprogrammet for Horns Rev 1 vindmølleparken (HR1).

Tilladelsen til at bygge Horns Rev 2 havvindmølleparken blev givet af Energistyrelsen den 19. marts 2007 på basis af DONG Energy's ansøgning af 13. oktober 2006. Placeringen af vindmølleparken er planlagt til at være på den ydre del af Horns Rev, og møl-leparken består af 91 møller på hver 2.3 MW, som er placeret i 13 øst-vestgående rækker med hver 7 møller. Overvågningen af fugletrækket blev udført ved hjælp af kombinerede visuelle observationer og radarundersøgelser. På grund af den sene start på anlægsarbejdet af Horns Rev 2 mølleparken blev kun forårsperioden dækket, og ingen faste platforme kunne anvendes til montering af radar i området. Derfor måtte radarstudiet udføres ved hjælp af radar monteret på båd, ankret ved de to mølleparker, kombineret med visuelle observationer og en observationsplatform ved Blåvands Huk. Der anvendtes X-båndsradar på henholdsvis 12 kW (Furuno FR 2105) og 25 kW (Decca BridgeMaster E) til radarundersøgelserne. Begge radaropsætninger kørte med horisontalt roterende antenne.

Post-processeringen af de indsamlede data blev udført med det formål at sammenligne bevægelserne af fugle ved de to ankerpladser ved Horns Rev 1 og 2 og sammenligne resultaterne for Horns Rev med resultaterne fra Blåvands Huk i relation til timing, intensitet, retning, trækhøjde og artssammensætning. Radarbillederne fra den horizontale radar blev opfanget fra skærmsignalet ved hjælp af et skærmfangerkort og specialbygget software SWARM (TriOS Mess- und Datentechnik, Oldenburg). Et skærmbillede blev gemt pr. minut og et samlet billede hver femte minut. Alle radarbilleder blev overført til GIS database, hvilket tillod analyser af trækruter og mønstre af de kortlagte ruter. Trækintensiteter blev estimeret ved hver af de tre stationer både som totaler for alle observerede fugle og for udvalgte arter og artsgrupper korrigerede i forhold til indsats. For at demonstrere den åbenbare koncentration af fuglebevægelser nær kysten blev der foretaget en profilanalyse af trækintensiteterne mellem Horns Rev 1 og Blåvands Huk, baseret på data fra Blåvands Huk, hvor data fra den faste radarinstallation tillod analyser ud til 15 km's afstand.

Bevægelserne af fugle domineredes ved begge offshore-stationer af andefugle, terner og måger med Sortand, Sølvmåge, Sildemåge, Stormmåge og Splitterne som de vigtigste arter. Idet disse artsgrupper generelt var stationære i området igennem længere tid vurderes det, at mere end 80 % af observationerne ved både Horns Rev 1 og 2 drejede sig om fourageringsbevægelser og bevægelser af rastende fugle. Lommer observeredes hyppigere ved Horns Rev 2, medens sortænder observeredes hyppigere ved Horns Rev 1. Langt hovedparten af observationerne ved Blåvands Huk blev udgjort af typiske kystfuglearter, og ingen bevægelser af landfugle blev noteret. De tre hyppigste arter ved Blåvands Huk var Sortand (57.6 %), lommer (15.6 %) og Islandsk Ryle (4.7 %).

Som et resultat af dominansen af sortænder, terner og måger udviste bevægelserne af fugle generelt en koncentration i højdeintervallet fra havoverfladen til 20 m. Ved Blåvands Huk blev der på grund af trækkende gæs registreret en større andel af fugle i intervallet mellem 40 og 200 m.

Undersøgelsen afslørede en lav intensitet af flyvende fugle over Horns Rev i undersøgelsesperioden, og så godt som ingen egentlige trækbevægelser i dagtimerne – de fleste registrerede fugle drejede sig om lokale fourageringsbevægelser i alle retninger. Imellem Horns Rev 1 og Blåvands Huk viste profilanalyser en markant stigning i intensiteten af fuglebevægelser tæt på kysten af Blåvand. Generelt var bevægelsesintensiteterne meget højere for både træk og fourageringsbevægelser nær kysten end offshore. Bevægelserne af fugle ved Blåvands Huk var domineret af sydgående strømkompensationsbevægelser af vandfugle.

Fugletrækstudiet indikerede, at bevægelser drevet af lokale og i de fleste tilfælde moderate koncentrationer af fouragerende fugle er de vigtigste på Horns Rev om foråret, hvorimod kompensationsbevægelser af Sortand er vigtigst nær Blåvand. Dette støttes af baselineundersøgelserne af rastende fugle gennemført i samme periode, der viste en koncentration af sortænder nær Blåvands Huk og kun få fødesøgende fugle på selve Horns Rev. På grund af den lave trækintensitet og det lave antal sortænder på Horns Rev var det ikke muligt at gennemføre registreringer af reaktioner hos trækkende fugle på Horns Rev 1 vindmølleparken. Herudover blev forudsætningerne for at følge adfærdsændringer hos fugle, der passerede vindmølleparken, begrænset af den korte detektionsradius ved anvendelsen af skibsbaseret radar.

Den lave tæthed af fuglebevægelser og fugletræk ved Horns Rev om foråret indikerer, at potentielle barriereeffekter af de to vindmølleparker på langdistancetrækket vil være begrænsede. De radarbaserede profilanalyser antydede imidlertid, at bevægelser af sortænder forekommer uregelmæssigt offshore, og flytællingerne gennemført i området gennem de sidste fem år har vist, at en større andel af sortænderne kan forekomme over den vestlige del af revet, specielt sidst på vinteren. Det skal bemærkes, at potentialet for barriereeffekter på langdistancetrækket kan være større under efterårstrækket, hvor et langt større volumen af fugle passerer området sammenlignet med om foråret.

Da de eksisterende data på fugletrækket over Horns Rev, som blev indsamlet under PSO-programmet, ikke dækkede de centrale og vestlige dele af området vurderes den samlede database at være utilstrækkelig som baseline for overvågningsprogrammet for HR2. Derfor er baselinen udvidet til efteråret 2008 ved anvendelse af 25 kW radarer med løbende registreringer fra faste radarinstallationer på de nye fundamenter, fra HR1 transformerstationen og fra Blåvands Huk.

2 INTRODUCTION

2.1 Background

DONG Energy has commissioned a consortium of Orbicon and DHI in association with BIOLA to undertake baseline investigations and monitoring of migratory birds as part of the monitoring program for the planned Horns Rev 2 offshore wind farm (HR2 OWF). The establishment of the HR2 OWF was granted by the Department of Energy on the 19th March 2007 on the basis of DONG Energy's application of 13th October 2006.

This report contains the results of the baseline monitoring on bird migration undertaken March-April 2008.

2.2 The Horns Rev II Project

2.2.1 Location

The location of the HR2 OWF is planned for the outer part of Horns Rev, a sand bank which stretches from the coast of Denmark (Blåvands Huk) and 40 km westwards, see Figure 2-1. The distance from the HR2 OWF to Blåvands Huk is 30 km. The minimum distance between the existing OWF on Horns Rev and the planned HR2 OWF is 14 km. The water depth at the site of the HR2 OWF varies between 6 and 18 m. The HR2 OWF has been designed as an arc north of the shallow VovVov on the western Horn Rev.

The HR2 OWF consists of a total of 91 turbines, each 2.3 MW which are placed with 13 east-west oriented rows of 7 turbines. Due to the design of the OWF the distance between the rows will vary from 700 m in the eastern part to 900 m in the western part, see Figure 2-1. The distance between individual turbines is 550 m.

Figure 2-1 and Figure 2-2 also show the proposed placement of three 15 MW test turbines. The transformer station will be located 1 km east of the wind farm. 16-20 m northeast of the transformer station an accommodation platform will be installed with a gangway connecting the two platforms.

The turbines will be connected by east-west running 34 kV cables, which will be collated into a single cable in the eastern part of the OWF, which then is connected to the transformer station, Figure 2-2.

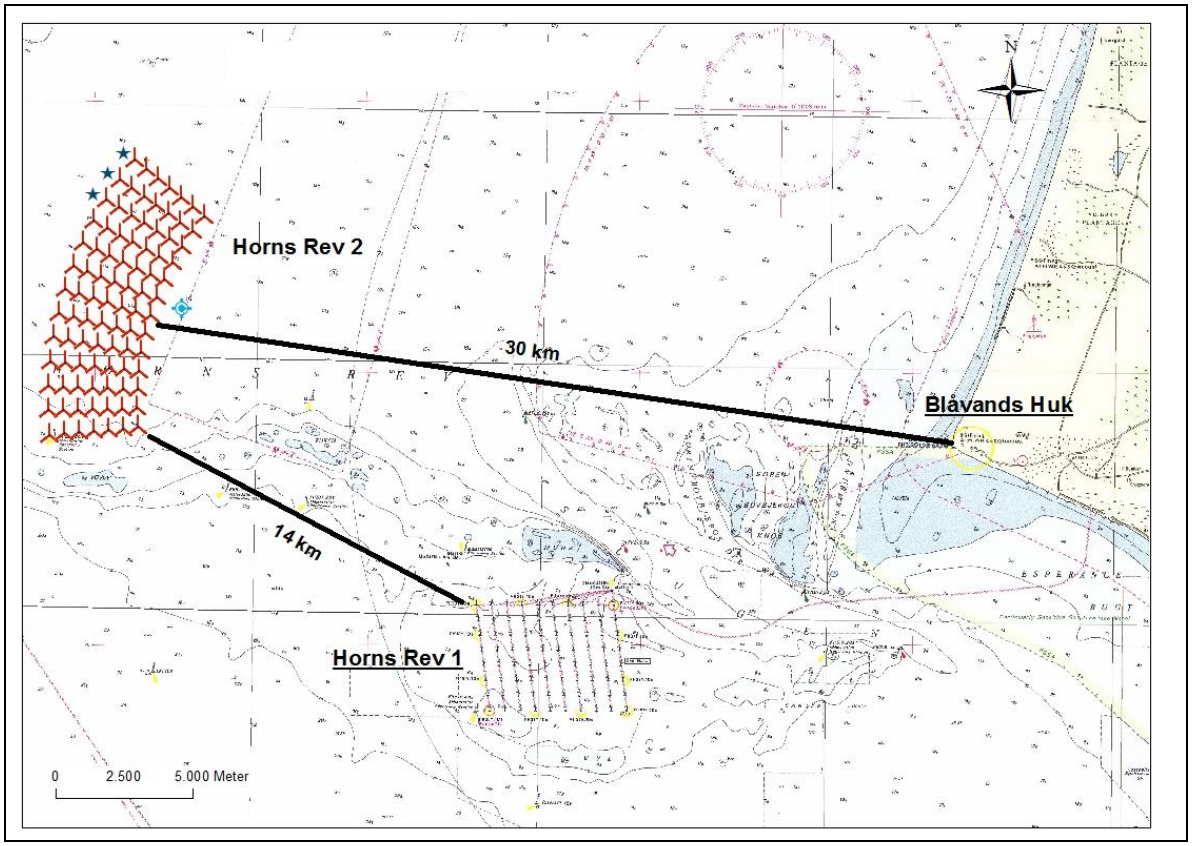

Figure 2-1. The location of the HR2 OWF relative to Blåvands Huk and the Horns Rev 1 OWF.

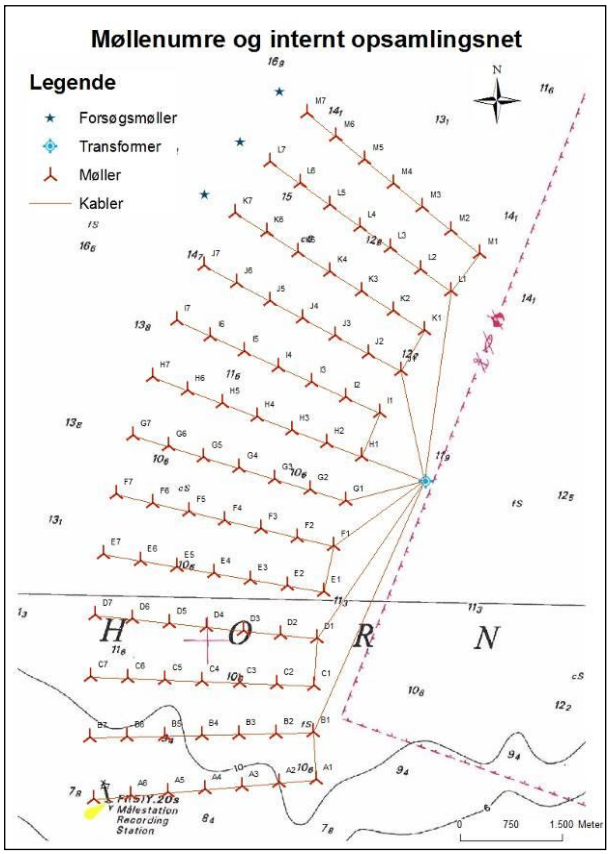

Figure 2-2. Turbine numbers and planned cables for the HR2 OWF.

2.2.2 Free zone

A free zone of 4 km towards the south and west and 2 km towards the north and east has been granted to DONG Energy for this OWF.

2.3 Monitoring requirements and targets in relation to bird migration

The requirements for the monitoring programme for Horns Rev 2 state that the methodologies should as far as possible been based on the same field methods as used in relation to the PSO monitoring programme for the HR1 OWF and in the investigations carried

out as part of the EIA for the HR2 OWF. Thus, the monitoring of bird migration has been based on application of horizontal ship radar to measure lateral changes in migration routes. The study focused on the long-distance migration of waterbirds across and along Horns Rev during spring in order to describe any impacts of the construction of the HR2 OWF on migratory birds and to describe any cumulative effects, here especially potential barrier effects as a consequence of both HR1 and HR2 OWF's. The statistical design of the monitoring program is based on the BACI approach. As all radar recordings will be stored in a raster GIS analyses can be designed to compare before/after construction scenarios for freely chosen areas around the two wind farms. The impact and control sites will be selected so that the recordings obtained during the PSO monitoring programme can be integrated into the analyses.

3 METHODS

3.1 Study period

Due to the late start of the project, the study period for the investigation has been chosen from March to May 2008, and studies during autumn 2007 were cancelled.

3.2 Study area and diurnal period

The original investigation design aimed at using fixed installations for the radar study: a land-based radar at Blåvands Huk, a radar mounted on one of the foundations at the HR2 OWF and the radar on the transformer station at the HR1 OWF (already installed). As construction work at the HR2 OWF was postponed until June 2008 the design had to be changed, and data on migrating birds were obtained by operating from an anchored vessel at HR1 and HR2 in combination with visual observations and a fixed installation at Blåvands Huk

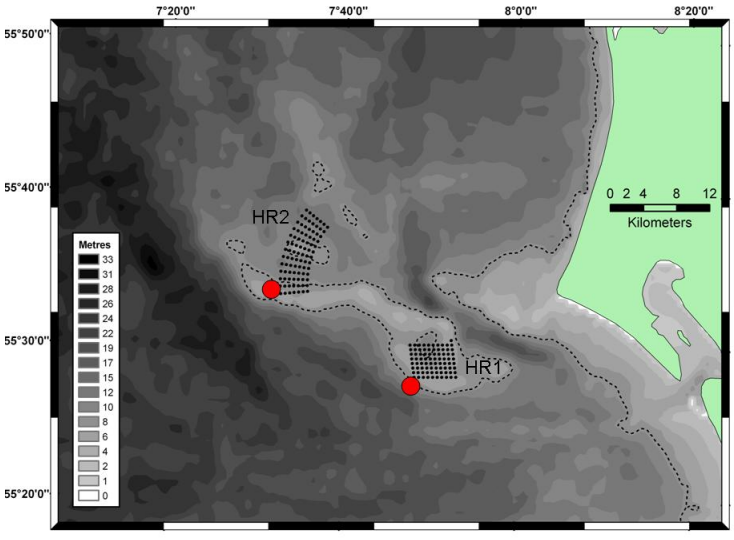

Figure 3-1: The anchoring positions for the radar observations at HR1 and HR2 OWF's.

The survey vessel was MV Salling/Esbjerg, a vessel of 41 m length. The anchoring positions were the south-western corner of the two wind farms (Figure 3-1).

In addition, radar investigations and visual observations were carried out at a land-based observation point at Blåvands Huk, position 55°32.420N / 08°04.300 E.

In order to conduct ship-based studies of bird migration weather conditions have to be favourable. A sea state higher than 2 (waves > 0.5 – 1 m) will produce considerable disturbance on the radar screen and will influence analyses of data at lower altitudes. Rain will clutter radar screens. Accordingly, in the North Sea favourable weather conditions for collection of radar data on migratory birds are restricted to a few days a year.

The weather conditions in spring 2008 were unusually unsuitable in the study area, and data on bird migration could only be collected during ten days at the anchoring positions at HR1 and HR2 OWF's resulting in a total of 247 hours of visual observations. The radar observations were possible only on four days at HR1 and six days at HR2 (Table 3-1) due to the weather conditions and in addition radar observations in some cases were only possible during parts of the day. The study aimed to focus on migrating birds why the period to cover was the main migration period. Thus investigations were carried out between March 25th and May 9th. Details of trips and effort are listed in Table 3-1.

Table 3-1: Observation periods and effort days at the anchoring positions Horns Rev I (HR I) and Horns Rev II (HR II)

Observation period	Effort days HR I	Effort days HR II	Days in which radar recordings were possible	
			HR I	HR II
25.03. - 27.03.08	1	1		1
30.03 - 31.03.08	1		1	
03.04 - 07.04.08	2	3		1
22.04 - 27.04.08	3	2		
28.04 - 29.04.08	1		1	
30.04 - 05.05.08	1	4	1	4
08.05 - 09.05.08	1		1	
	10	**10**	**4**	**6**

At Blåvands Huk, Figure 3-2, a total of 30 effort days for visual observations and 27 effort days for radar investigations were carried out between March 7th and May 10th,

.

Figure 3-2: The observation platform and mounted radar at Blåvands Huk.

Table 3-2: Observation days and effort days of visual observations and radar investigations at Blåvands Huk

Observation day	Effort days visual observations	Effort days radar investigations
07.03.2008	X	
08.03.2008	X	
09.03.2008	X	
10.03.2008	X	
11.03.2008	X	
14.03.2008	X	X
15.03.2008	X	X
16.03.2008	X	X
17.03.2008	X	X
19.03.2008	X	X
20.03.2008	X	X
22.03.2008		X
23.03.2008	X	X
24.03.2008		X
25.03.2008	X	X
04.04.2008	X	X
05.04.2008	X	X
23.04.2008	X	X
24.04.2008	X	X
25.04.2008	X	X
26.04.2008	X	X
27.04.2008	X	X
28.04.2008	X	X
29.04.2008	X	X
30.04.2008	X	X
01.05.2008	X	X
05.05.2008	X	X
06.05.2008	X	X
07.05.2008	X	X
08.05.2008	X	X
09.05.2008	X	X
10.05.2008	X	X
	30	**27**

3.3 Radar and visual observations of bird migration and selected species

3.3.1 Ship-based study on Horns Rev and land-based study at Blåvands Huk

Radar investigations

Two X-band ship surveillance radars with a power output of 12 kW and 25 kW, respectively, were used for the radar observations. They were both operated with the antenna rotating horizontally. The two radar devices in use were a Decca "BridgeMaster E" at

Blåvands Huk and a Furuno "FR 2105" on the vessel. For technical specifications of the radar devices see Table 3-3.

Table 3-3: Specifications of radar devices used at Blåvands Huk (Decca Litton) and on the vessel Salling (Furuno)

Brand	**Decca Litton Marine Systems**	**Furuno**
Type	**BridgeMaster E-series**	**FR 2105**
Power output [kW]	25	12
Frequency	9,410±30 / ~31,86	9,410±30 / ~?
Horizontal angle of radar	1	1,8
Vertical angle of radar	24	25
Rotational speed [min^{-1}]	28/45	24
Antenna length [mm]	2,440	1,983

The horizontal radar aimed to show flight directions of birds and flight intensities outside the range of the visual observations. The range was set to 3 nautical miles (~5,556 m). A prerequisite for the use of horizontal radar is a calm sea state (< 3 m/s). Otherwise the signals will be concealed by sea clutter, caused by the reflection of the radar waves by a rough water surface. A filter to suppress the sea clutter was used to a certain extent if necessary. The gain was tuned to the highest possible level before error echoes appeared. Wake duration (defining the length of the target trail) was set to maximum level. The used radars are in most situations capable of tracking flocks of waterbirds at a distance of at least 5 km.

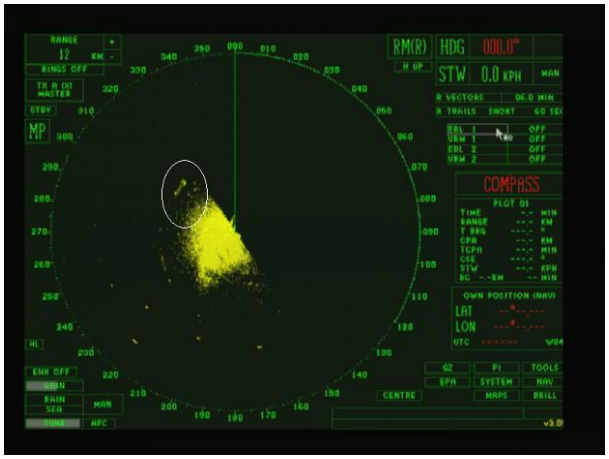

Figure 3-3. Radar echo of a flock of Common Scoters.

Visual observations

Visual observations were carried out from a location on the vessel providing good surround-view combined with good accessibility and a reasonable height above water level which is necessary to detect and track flying birds. On MV Salling this location was the stern deck with ca. 5 m height above sea level.

Visual observations of flying birds (including migration as well as movements from/to/between feeding and/or resting sites) took place during daylight hours from before sunrise until after sunset including the twilight periods of some 20-30 min before sunrise and after sunset, as long as light conditions allowed. Birds were counted during intervals of 15 minutes each (one per every half hour), with a minimum of 5 minutes between the intervals. In every counting unit one experienced observer registered all flying birds and noted the species (whenever identification was possible), distance from the observer, flight direction and flight altitude. Furthermore data about age and sex of

the birds were gathered if possible as well as the birds' association with vessels and behavioural remarks according to the international ESAS codes (Camphuysen & Garthe 2001). Special attention was paid to spatial reactions to the windmills at Horns Rev I. Optics used by the observers were binoculars with 10x magnification.

The focus of the visual observations was set on recording flight movements of Common Scoter (*Melantita nigra*), divers (*Gavidae sp*.) and other waterfowl. Additionally, further data of offshore migrating or other moving birds were recorded.

3.4 Data analyses

3.4.1 Post-processing and establishing of digital databases of flight trajectories and migration intensities

Visual observations

Data from the visual observations were logged to database as totals for each 15 min counting period with details of species, distance and behaviour. Post-processing was made with the purpose to compare bird movements observed at the two anchoring positions at the HR1 and HR2 OWF's as well as to compare the results of bird migration/movements at Horns Rev with those at Blåvands Huk in terms of timing, intensity, direction, flight altitude and species composition.

Data were also analysed with respect to specific reactions assumed to be caused by the HR1 wind farm.

Radar observations

Each echo on the radar monitor corresponded to a single bird or a flock in the study area, and in this way the spatial pattern of migration in this area of open sea could be described. Bird echoes on the radar monitor appear as distinct dots moving at different velocities. Each migration trajectory was mapped by tracing the course of bird flocks from the radar monitor into a computer using either a GIS software or a software like Offshore Navigator, where the track could be stored as a route. Periods with no bird activity were noted. To determine species involved for each of the radar tracks, visual observations were coordinated with radar observations during daytime by direct communication between the radar operator and the visual observer or at Blåvands Huk by the same observer.

Radar images of the horizontal radar were captured from the screen signal via video splitter by a framegrabber card on a PC using custom-made software called SWARM (by TriOS Mess- und Datentechnik, Oldenburg). One screenshot was stored every minute and a cumulative picture every 5 minutes. All radar recordings were transferred to a GIS database allowing the analyses of flight directions and patterns of tracked trajectories.

3.4.2 Estimation of flight intensities

At each location, flight intensities were estimated both as effort-corrected totals for all birds recorded and for selected species groups (visual observations). In addition, to demonstrate the apparent concentration of bird movements and migration near the coast during the study period flight intensities were estimated in relation to distance from the coast at Blåvands Huk. An analysis of flight intensities with distance was made using radar data and summarising flight intensities in 15 north-south oriented transects, each with a width of 1 km, extending from the coast to the HR1 OWF.

3.4.3 Establishment of BACI design

Three main hypotheses relating to the long-distance migration of waterbirds have been formulated on the basis of the results of the Horns Rev 1 monitoring programme (Petersen et al. 2006). Firstly, it is expected that waterbird migration routes will change systematically at close distances to the wind farm. Secondly, the number of crossings in the wind farm will be reduced after construction. Changes in flight directions may take place closer to the wind farms in poor visibility, and hence the number of crossings is likely to be higher during these conditions. The linked third hypothesis covers the cumulative effects of both wind farms predicting only short-scale (< 1 km) changes in flight directions and thus no or only limited barrier effects on the overall movements of waterbirds which cross Horns Rev during spring and autumn migration. The tests of the changes in migration routes and flight intensity at both wind farm areas and the coast will be made on the basis of BACI tests.

3.5 Quality control

After each day of visual and radar observations we checked both databases and screenshots for completeness. As soon as possible after each field campaign the data were transferred to GIS databases. Later on the data sets were run through different routines to detect mistyping and other errors. Finally, a senior researcher evaluated the data.

General quality assurance and management are conducted and documented in accordance with internationally accepted principles for quality and environmental management as described in the DS/EN ISO 9001 standard

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4 RESULTS

4.1 Species composition

4.1.1 Ship-based investigations at Horns Rev

The species composition for both anchoring positions Horns Rev I and Horns Rev II is listed in Table 4-1. In some cases birds could not be identified to species level. These birds were identified to the highest possible taxonomic level.

During visual observations at Horns Rev a total of 11,510 individual birds were recorded. Altogether, 49 different bird species and 15 species groups were observed. At the anchoring position Horns Rev I, 28 bird species and 11 species groups with a total of 6,160 individuals were found. At the anchoring position Horns Rev II, species composition had a wider range (45 bird species and 11 species groups), while the number of recorded individuals (5,350) was less than at Horns Rev I.

Besides typical coastal water birds such as geese, ducks, terns, divers and gulls several pelagic species were recorded (Fulmar, Gannet, Kittiwake, Guillemot, Puffin and Razorbill) as well as a wide range of migrating songbirds. Especially, some species of pelagic birds, songbirds, waders, birds of prey and ducks were solely observed at Horns Rev II. Migratory birds (e.g. songbirds, geese, waders, owls), although recorded in moderate number, occurred in larger numbers at Horns Rev II (25 species) than at Horns Rev I (15 species).

Table 4-1: Species and numbers recorded at the anchoring positions Horns Rev I (HR I) and Horns Rev II (HR II) during spring 2008

		HR I		HR II	
Species (lat.)	**Species (engl.)**	**Number**	**%**	**Number**	**%**
Alca torda	Razorbill			4	0.1
Alca torda / Uria aalge	Common Guillemot/Razorbill			4	0.1
Anas crecca	Green-winged Teal			8	0.1
Anas penelope	Eurasian Wigeon			4	0.1
Anatinae indet.	Duck sp.	22	0.4		
Anserini indet.	Grey Goose sp.			196	3.7
Anthus pratensis	Meadow Pipit	6	0.1	58	1.1
Asio flammeus	Short-eared Owl			2	0.0
Aves spec.	Species unknown			2	0.0
Calidris alpina	Dunlin			12	0.2
Cepphus grylle	Black Guillemot			2	0.0
Circus aeruginosus	Marsh Harrier			2	0.0
Corvus frugilegus	Rook	2	0.0	2	0.0
Erithacus rubecula	Robin			2	0.0
Falco columbarius	Merlin	2	0.0		
Falco tinnunculus	Eurasian Kestrel			2	0.0
Fratercula arctica	Puffin			2	0.0

Species (lat.)	Species (engl.)	HR I		HR II	
		Number	%	Number	%
Fringilla coelebs	Chaffinch			2	0.0
Fulmarus glacialis	Northern Fulmar			18	0.3
Gavia stellata	Red-throated Diver	12	0.2	12	0.2
Gaviidae indet.	Diver sp.	4	0.1	14	0.3
Haematopus ostralegus	Oystercatcher	6	0.1		
Hirundo rustica	Swallow	28	0.5	10	0.2
Laridae indet.	Gulls sp.	406	6.6		
Larus / Rissa indet.	Lesser Gull sp.	12	0.2		
Larus argentatus	Herring Gull	132	2.1	424	7.9
Larus argentatus / canus	Herring/Common Gull	2	0.0	2	0.0
Larus canus	Common Gull	238	3.9	94	1.8
Larus fuscus	Lesser Black-backed Gull	248	4.0	252	4.7
Larus marinus	Great Black-backed Gull	86	1.4	30	0.6
Larus melanocephalus	Mediterranean Gull	4	0.1	2	0.0
Larus minutus	Little Gull	40	0.6	36	0.7
Larus ridibundus	Black-headed Gull	82	1.3	16	0.3
Larus spec.	large gull sp.	142	2.3	204	3.8
Limicolae indet.	Wader sp.	40	0.6		
Melanitta fusca	Velvet Scoter			22	0.4
Melanitta nigra	Common Scoter	2,164	35.1	1,554	29.0
Motacilla alba	White Wagtail	2	0.0	10	0.2
Motacilla cinerea	Grey Wagtail			2	0.0
Numenius arquata	Curlew			2	0.0
Oenanthe oenanthe	Wheatear	2	0.0	2	0.0
Passeriformes indet.	Passerines sp.	40	0.6	8	0.1
Phalacrocorax carbo	Great Cormorant	12	0.2	80	1.5
Philomachus pugnax	Ruff			14	0.3
Phylloscopus collybita	Chiffchaff	2	0.0	2	0.0
Regulus ignicapillus	Firecrest			2	0.0
Rissa tridactyla	Kittiwake	36	0.6	20	0.4
Somateria mollissima	Common Eider	12	0.2		
Stercorarius parasiticus	Arctic Skua	24	0.4	22	0.4
Stercorarius parasiticus / pomarinus	Arctic/Pomarine Skua	6	0.1	4	0.1
Stercorarius pomarinus	Pomarine Skua	2	0.0	2	0.0
Stercorarius skua	Skua			2	0.0
Sterna hirundo	Common Tern	6	0.1	44	0.8
Sterna hirundo / paradisaea	Common/Arctic Tern	94	1.5	184	3.4
Sterna paradisaea	Arctic Tern			6	0.1
Sterna sandvicensis	Sandwich Tern	1,500	24.4	1,612	30.1
Sterninae indet.	Tern sp.	6	0.1	4	0.1
Sturnus vulgaris	Common Starling	632	10.3	110	2.1
Sula bassana	Northern Gannet	100	1.6	198	3.7
Troglodytes troglodytes	Wren (Winter Wren)			2	0.0
Turdidae indet.	Thrush			20	0.4
Turdus iliacus	Redwing	4	0.1		
Turdus merula	Blackbird			2	0.0
Turdus philomelos	Song Thrush	2	0.0	2	0.0
Species/Species groups		**39**		**56**	
Individuals		**6,160**		**5,350**	

The composition of species groups is shown in percentages of all observations in Figure 4-1 and Figure 4-2.

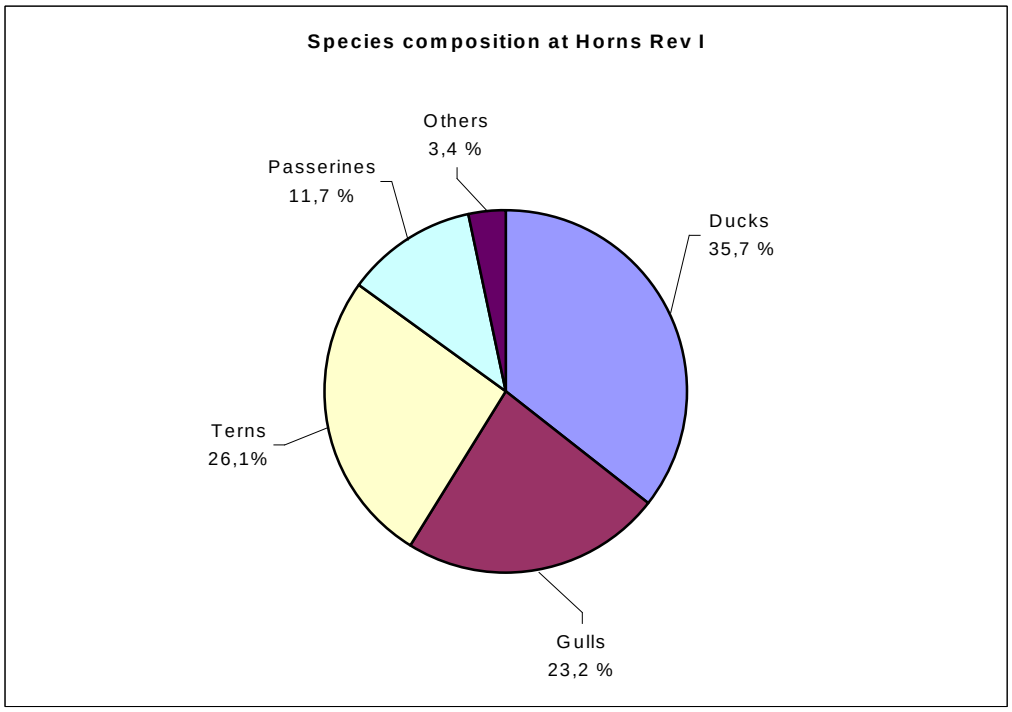

Figure 4-1. Species composition of recorded birds at the anchoring position Horns Rev I in spring 2008 (n = 6,160).

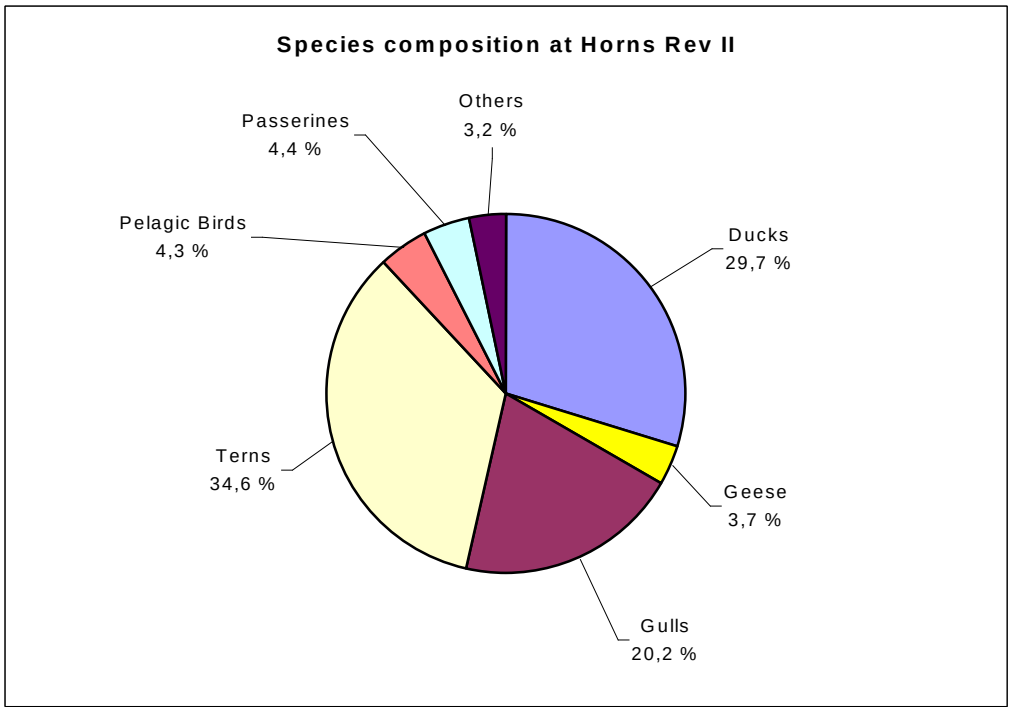

Figure 4-2. Species composition of recorded birds at the anchoring position Horns Rev II in spring 2008 (n = 5,350).

At both offshore sites, ducks, terns and gulls were the dominant groups, with Common Scoter, Herring Gull, Lesser Black-backed Gull, Common Gull and Sandwich Tern being numerically the most important species. As these species groups usually were stationary for longer periods and certain individuals were likely to be present in the area for the duration of several hours or even days, more than 80 % of the observations in both study areas might represent foraging flights or flights of resting birds. 11.7 % (HR I) and 4.4 % (HR II) of the recorded observations represented songbirds. Among them Common Starling was observed most frequently. Geese were only observed at Horn Rev II (3.7 %) and there too, pelagic birds showed a higher frequency of occurrence (4.3 %).

The following section describes the occurrence of the most abundant species and species groups, as well as species of special interest at both offshore investigation sites.

Divers

A total of 42 divers (*Gavia stellata* and *Gavia sp.*) were recorded during the visual observations. Divers were observed in somewhat lower frequencies in the area of the existing OWF HR I (16 individuals) as compared to the planned OWF HR II (26 individuals).

Common Scoter

With a total of 3,718 individuals Common Scoter (*Melanitta nigra*) was the most frequently observed species in the study areas. Of these 2,164 were observed at Horns Rev I and 1,554 at Horns Rev II. The frequency of occurrence was 35.1 % (HR I) and 29.0 % (HR II), respectively.

Terns

A total of 3,456 terns were recorded during the visual observations. With 1,606 recorded individuals (26.1 %) at Horns Rev and 1,864 individuals (34.6 %) at Horns Rev II, there was no obvious difference in the occurrence of terns in both study areas.

Gulls

A total of 2,508 gulls were recorded during the visual observations. Of these 1,428 were observed at Horns Rev I and 1,080 at Horns Rev II. The frequency of occurrence was 23.2 % (HR I) and 20.2 % (HR II) respectively.

4.1.2 Land-based investigations at Blåvands Huk

The species composition for the observation point Blåvands Huk is listed in Table 4-2.

During visual observations at Blåvands Huk a total of 20,715 individual birds were recorded. Altogether, 53 different bird species and 6 species groups were observed. The vast majority of the observations belong to typical coastal water birds such as geese, ducks, terns, divers, cormorants, waders or gulls. Among them, with 14 observed species, ducks formed a large fraction. Besides, two pelagic bird species and seven species of birds of prey were recorded. Songbirds did not occur at this observation point.

Table 4-2: Species and numbers recorded at the observation point Blåvands Huk during spring 2008

Species (lat.)	Species (engl.)	Number	%
Accipiter nisus	European Sparrow Hawk	1	0.0
Alcidae indet.	Auklets sp.	2	0.0
Anas acuta	Northern Pintail	32	0.2
Anas clypeata	Northern Shoveler	5	0.0
Anas crecca	Green-winged Teal	231	1.1
Anas penelope	Eurasian Wigeon	196	0.9
Anas querquedula	Garganey	1	0.0
Anas strepera	Gadwall	5	0.0
Anser anser	Grey Goose	134	0.6
Anser indet.	Unidentified Goose	20	0.1
Anser indicus	Bar-headed Goose	1	0.0
Ardea cinerea	Common Heron	1	0.0
Aythya ferina	Common Pochard	27	0.1
Aythya fuligula	Tufted Duck	9	0.0
Aythya marila	Greater Scaup	2	0.0
Branta bernicla	Brent Goose	22	0.1
Branta bernicla hrota	Light-bellied Brent Goose	12	0.1
Branta bernicla nigricans	Black-bellied Brent Goose	326	1.6
Branta leucopsis	Barnacle Goose	282	1.4
Bucephala clangula	Common Goldeneye	11	0.1
Calidris alpina	Dunlin	7	0.0
Calidris canutus	Knot	2,813	13.6
Chlidonias niger	Black Tern	2	0.0
Circus aeruginosus	Marsh Harrier	1	0.0
Circus cyaneus	Hen Harrier	1	0.0
Circus macrourus/pygargus	Pallid/Montegue's Harrier	1	0.0
Circus pygargus	Montagu’s Harrier	1	0.0
Clangula hyemalis	Long-tailed Duck	90	0.4
Falco subbeteo	Hobby	1	0.0
Falco tinnunculus	Eurasian Kestrel	1	0.0
Gavia adamsii	White-billed Diver	1	0.0
Gavia arctica	Black-throated Diver	20	0.1
Gavia immer	Great Northern Diver	2	0.0
Gavia sp.	Diver sp.	11	0.1
Gavia stellata	Red-throated Diver	869	4.2
Haematopus ostralegus	Oystercatcher	100	0.5
Laridae indet.	Gulls sp.	1,000	4.8
Larus argentatus	Herring Gull	1	0.0
Larus canus	Common Gull	10	0.0
Larus fuscus	Lesser Black-backed Gull	37	0.2
Larus marinus	Great Black-backed Gull	2	0.0
Larus minutus	Little Gull	1	0.0
Larus ridibundus	Black-headed Gull	5	0.0
Limosa lapponica	Bar-tailed Godwit	256	1.2
Melanitta fusca	Velvet Scoter	90	0.4
Melanitta nigra	Common Scoter	12,953	62.5
Mergus serrator	Red-breasted Merganser	39	0.2
Numenius arquata	Curlew	67	0.3
Numenius phaeopus	Whimbrel	1	0.0
Phalacrocorax aristotelis	Shag Cormorant	3	0.0
Phalacrocorax carbo	Great Cormorant	72	0.3

Species (lat.)	Species (engl.)	Number	%
Pluvialis apricaria	Golden Plover	25	0.1
Pluvialis squatarola	Grey Plover	10	0.1
Podiceps grisegena	Red-necked Grebe	2	0.0
Somateria mollissima	Common Eider	581	2.8
Stercorarius parasiticus	Arctic Skua	11	0.1
Sterna hirundo	Common Tern	139	0.7
Sterna hirundo/paradisaea	Common/Arctic Tern	48	0.2
Sterna paradisaea	Arctic Tern	17	0.1
Sula bassana	Northern Gannet	97	0.5
Tadorna tadorna	Shelduck	7	0.0
Species/Species groups		**61**	
Individuals		**20,715**	

The composition of species groups is shown in percentages of all observations in Figure 4-3.

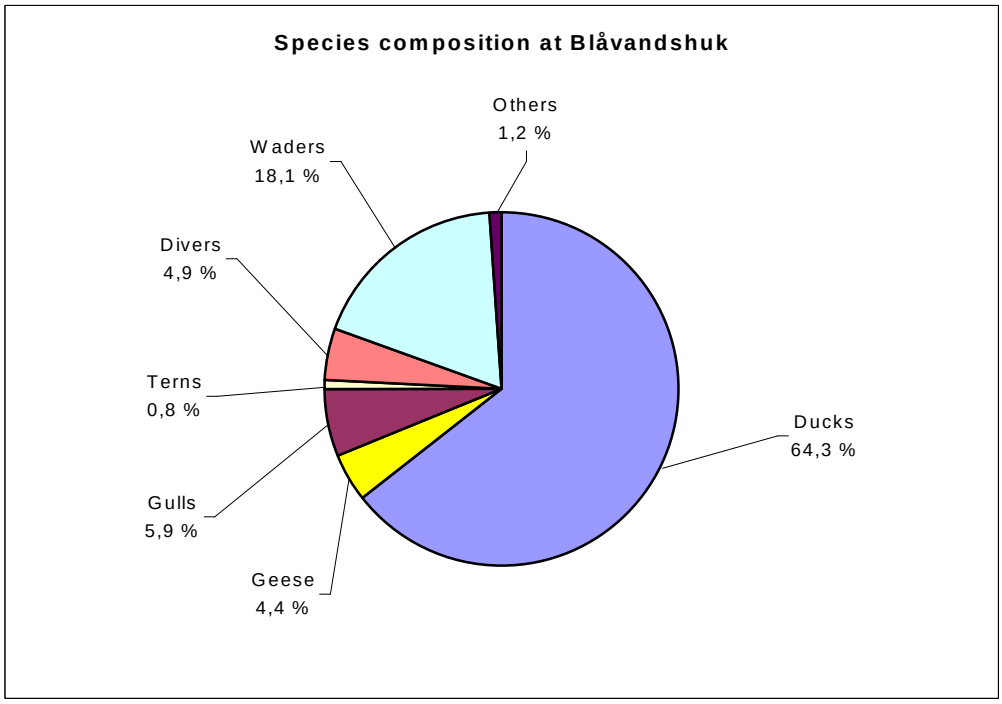

Figure 4-3. Species composition of recorded birds at the observation point Blåvands Huk in spring 2008 (n = 20,715)

At Blåvands Huk, 64 % of the recordings represented ducks. Although a large number of species was recorded, Common Scoter dominated the movements with 12,953 individuals and a proportion of 62%. Another important group were the waders, represented by 16 % of the recordings. Among them, Knot (*Calidris canutus*) was observed most frequently (14%). Divers represented a proportion of 4 % of the observations, with Red-throated Diver (*Gavia stellata*) being numerically the most important species (4 %). gulls and geese occurred with a proportion of 5% and 4% respectively. Terns (1 %) were far less abundant at Blåvands Huk as compared to the two offshore sites.

4.2 Migration intensity

4.2.1 Ship-based investigations at Horns Rev

The intensities of all flying birds for both anchoring positions at Horns Rev I and Horns Rev II are shown in Figure 4-4 and Figure 4-5.

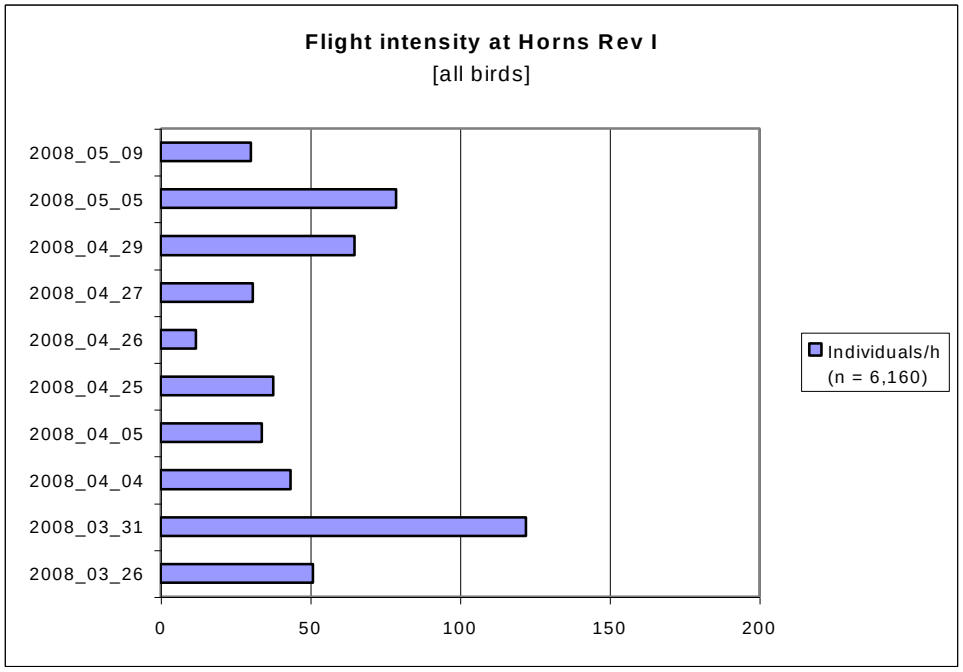

Figure 4-4. Flight intensity (individuals/h) of all birds recorded by visual observations at the anchoring position Horns Rev I in spring 2008.

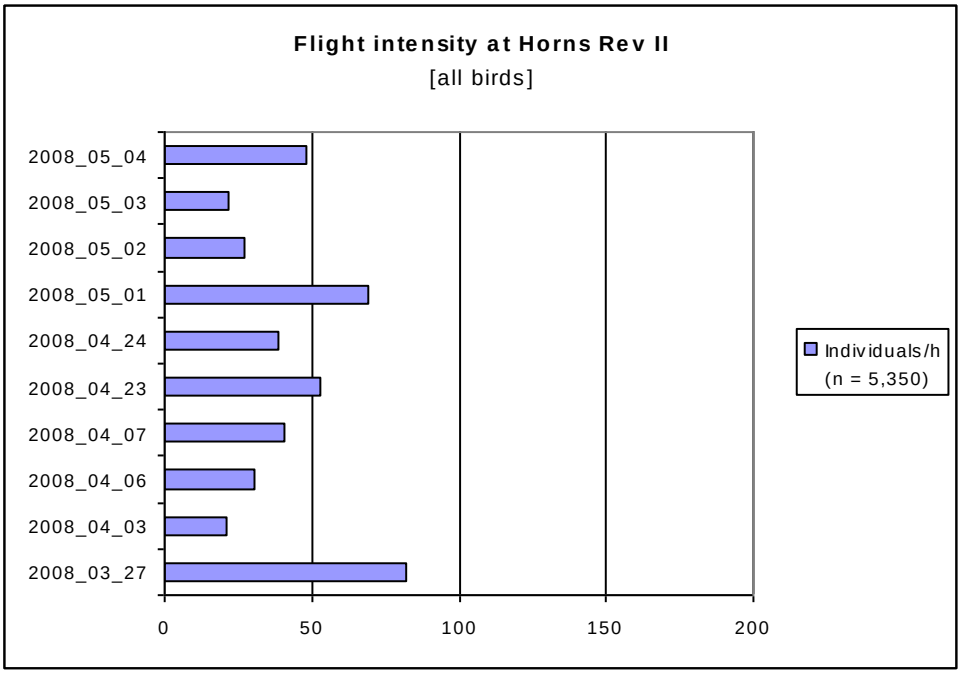

Figure 4-5. Flight intensity (individuals/h) of all birds recorded by visual observations at the anchoring position Horns Rev II in spring 2008.

As shown above, the vast majority of bird movements at the two offshore sites were of ducks, terns and gulls which are resting in the study areas for shorter or longer periods of time. Hence, the intensities shown in the figures above likely represent more foraging flights or flights of resting birds than flights of migrating birds.

Flight intensity at both study sites was generally relatively low. At Horns Rev I, on most observation days flight intensity was below 50 individuals/h. Only on March 31th some noticeable bird movements were recorded, resulting in the highest recorded flight intensity of 122 individuals/h. At Horns Rev II, flight intensity was generally a little lower than at Horns Rev I. On three of ten observation days more than 50 individuals/h were recorded. The highest flight intensity was found on March 27th (81.8 individuals/h).

The following figures show the flight intensities of Common Scoter, terns, gulls and other waterfowl at both anchoring positions Horns Rev I and Horns Rev II. Flight intensities of divers are not presented here because of their low frequency of occurrence.

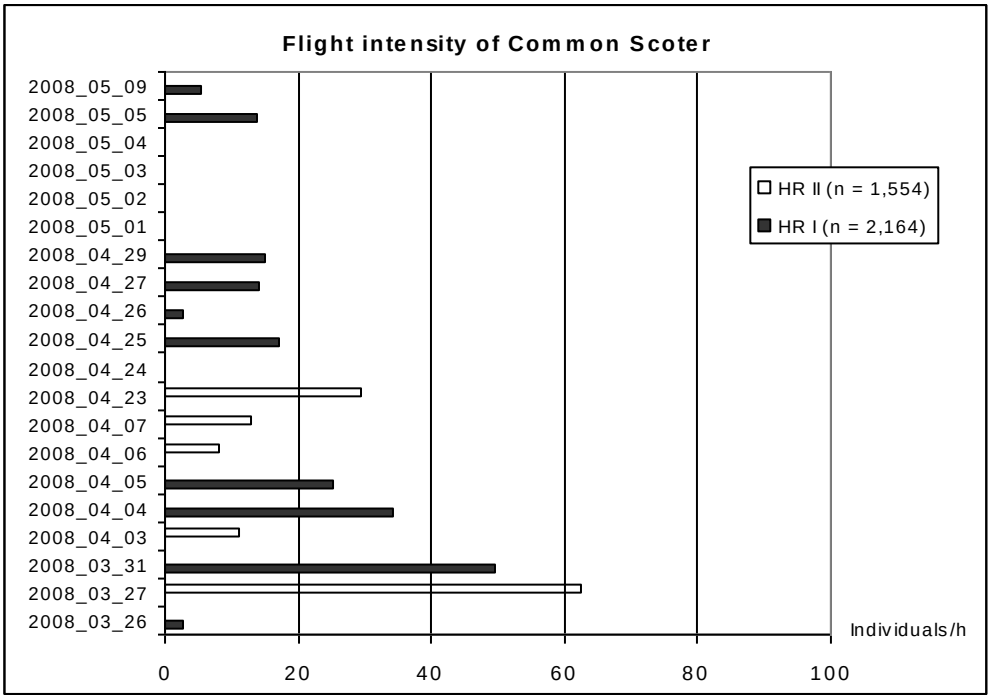

Figure 4-6. Flight intensity (individuals/h) of Common Scoter (Melanitta nigra) *recorded by visual observations at the anchoring positions Horns Rev I and Horns Rev II in spring 2008.*

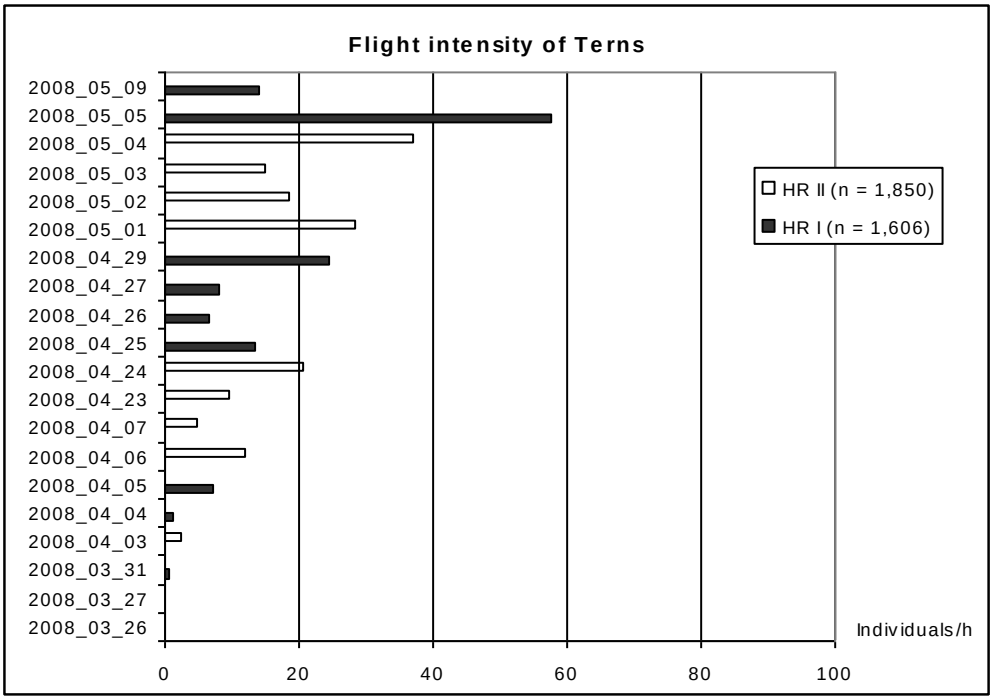

Figure 4-7. Flight intensity (individuals/h) of terns recorded by visual observations at the anchoring positions Horns Rev I and Horns Rev II in spring 2008.

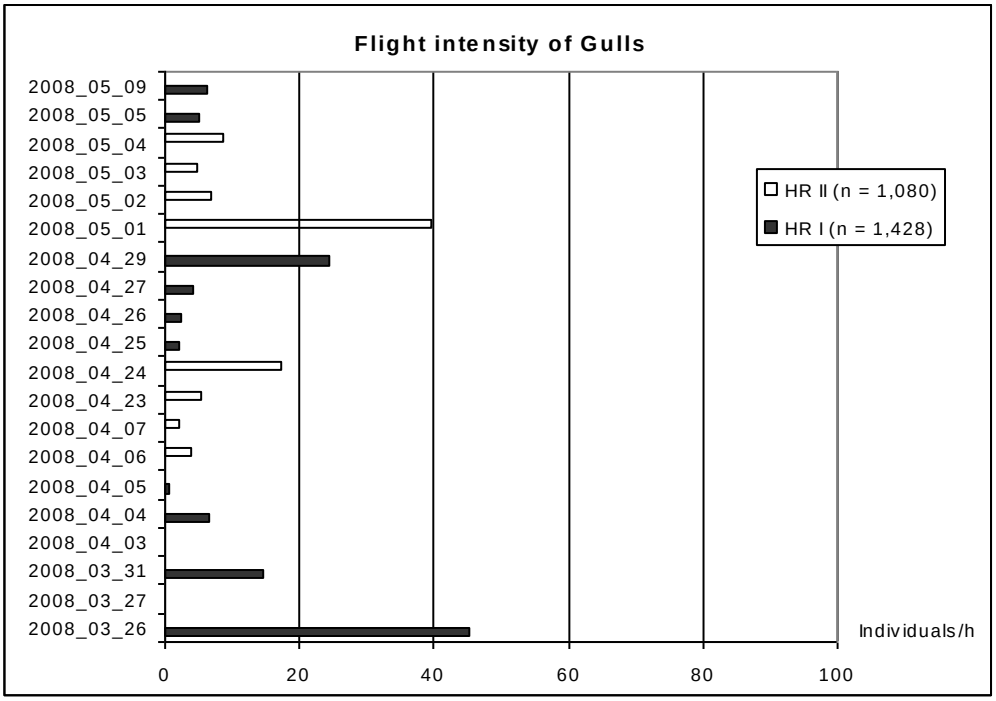

Figure 4-8. Flight intensity (individuals/h) of gulls recorded by visual observations at the anchoring positions Horns Rev I and Horns Rev II in spring 2008.

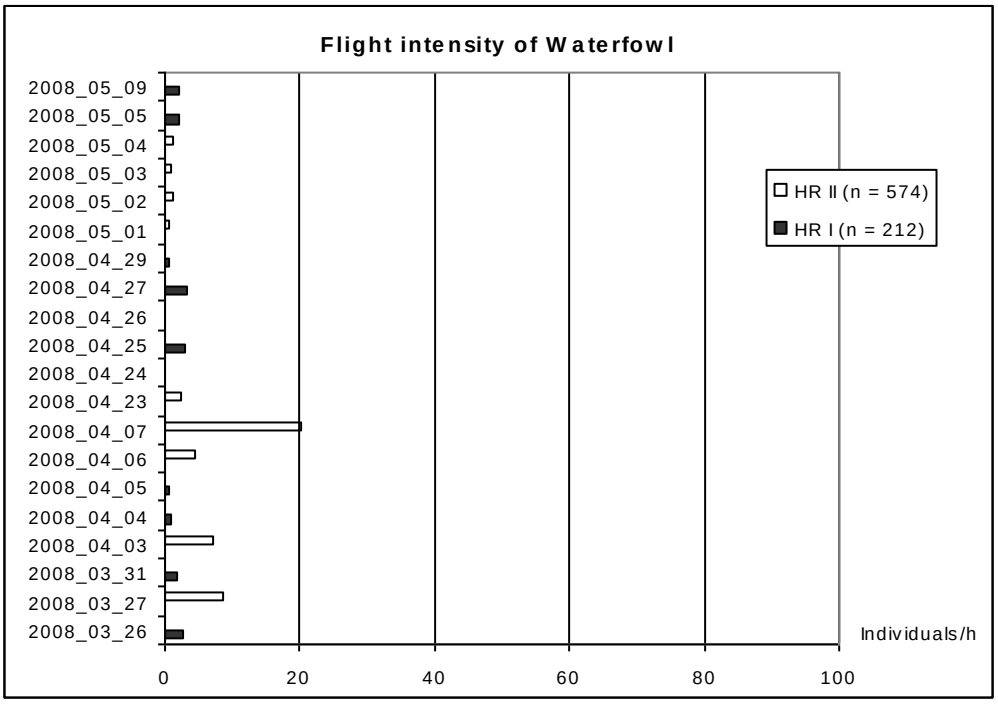

Figure 4-9. Flight intensity (individuals/h) of waterfowl (ducks, geese, cormorant, skuas, pelagic birds, waders) recorded by visual observations at the anchoring positions Horns Rev I and Horns Rev II in spring 2008.

4.2.2 Land-based investigations at Blåvands Huk

The intensities of all flying birds at the observation point Blåvands Huk is shown in Figure 4-10, and the flight intensities of Common Scoter, divers, terns, gulls, waders and geese are shown in Figures 4-11 – 4-16. For most groups flight intensities at Blåvands Huk were significantly higher than on Horns Rev, and intensities above 50 birds/h were recorded at approximately half of the observation days (13 days).

Two maxima were recorded, one in March dominated by Common Scoter, and one in early May dominated by waders. Noticeable low flight intensities were noted for terns as compared to the offshore sites, and high intensities for gulls were only recorded during a single day.

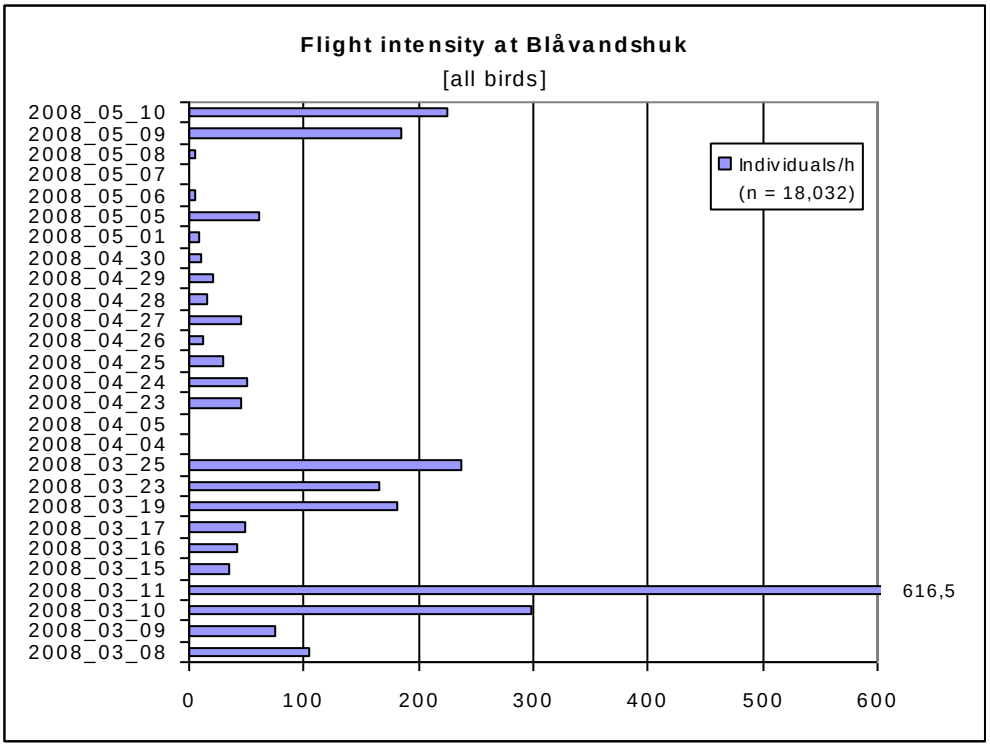

Figure 4-10. Flight intensity (individuals/h) of all birds recorded by visual observations at the observation point Blåvands Huk in spring 2008.

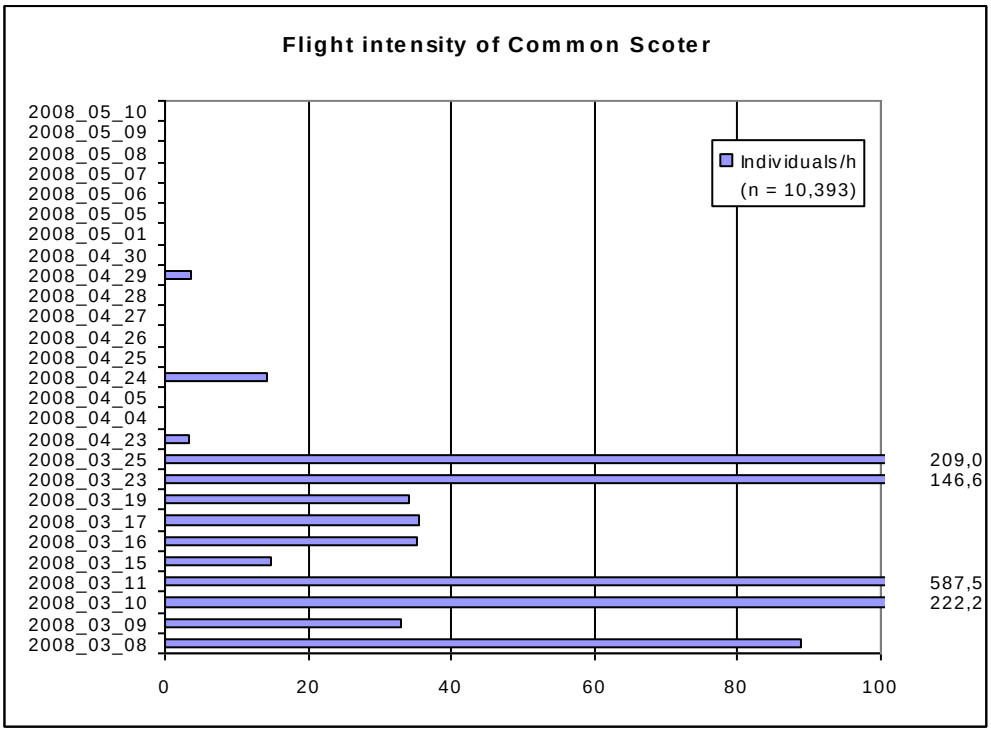

*Figure 4-11. Flight intensity (individuals/h) of Common Scoter (*Melanitta nigra*) recorded by visual observations at the observation point Blåvands Huk in spring 2008.*

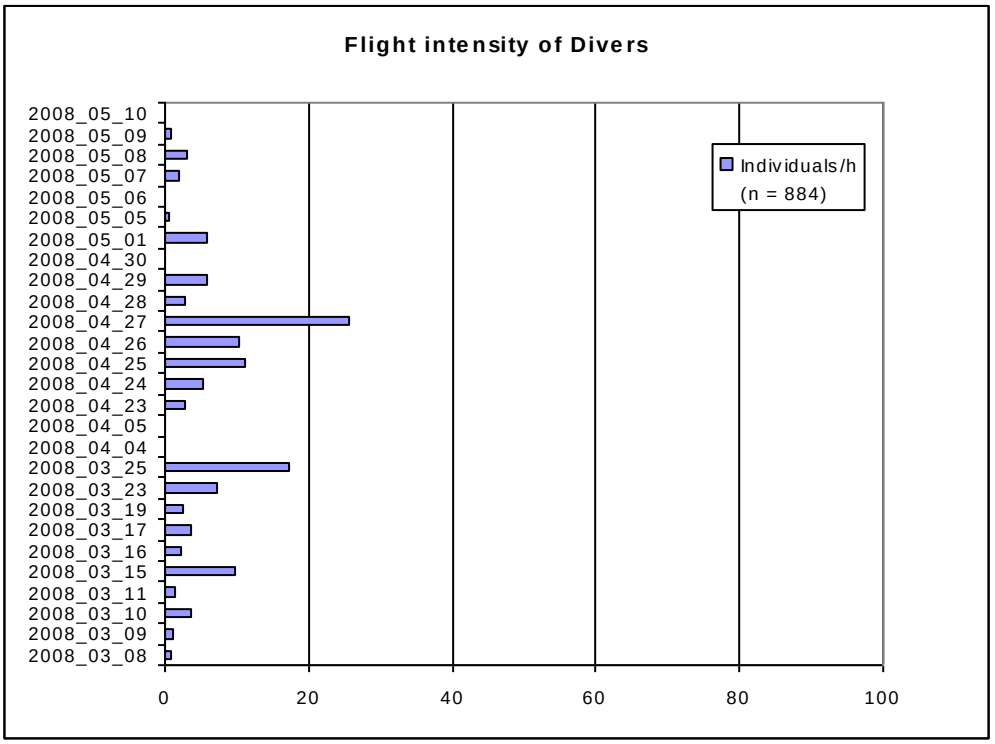

Figure 4-12. Flight intensity (individuals/h) of divers recorded by visual observations at the observation point Blåvands Huk in spring 2008.

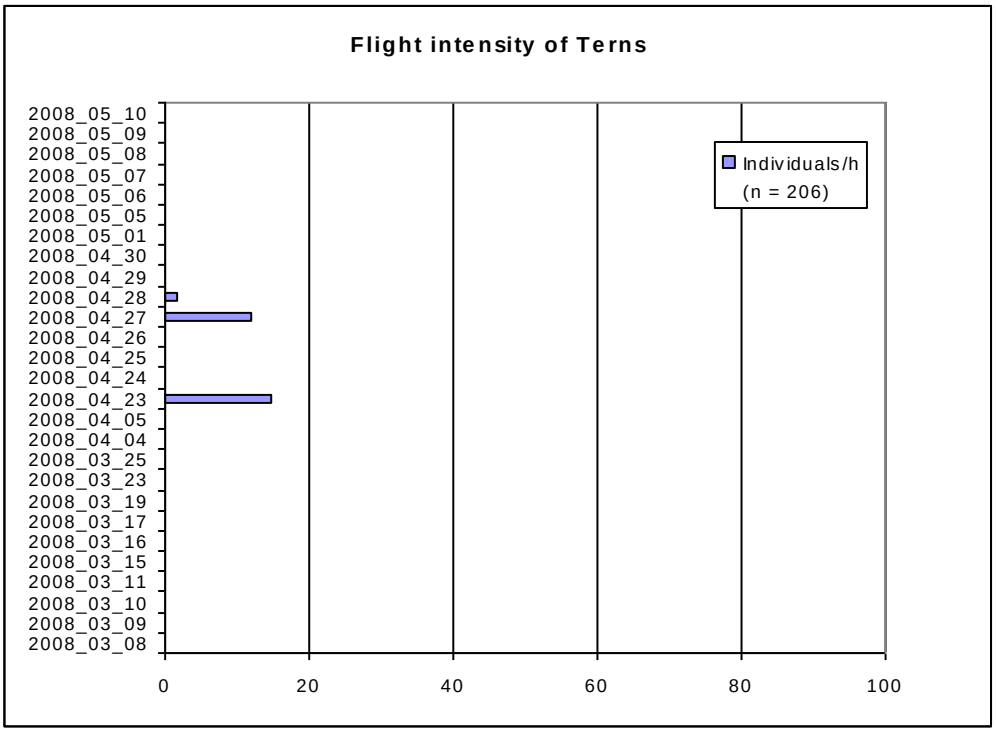

Figure 4-13. Flight intensity (individuals/h) of terns recorded by visual observations at the observation point Blåvands Huk in spring 2008.

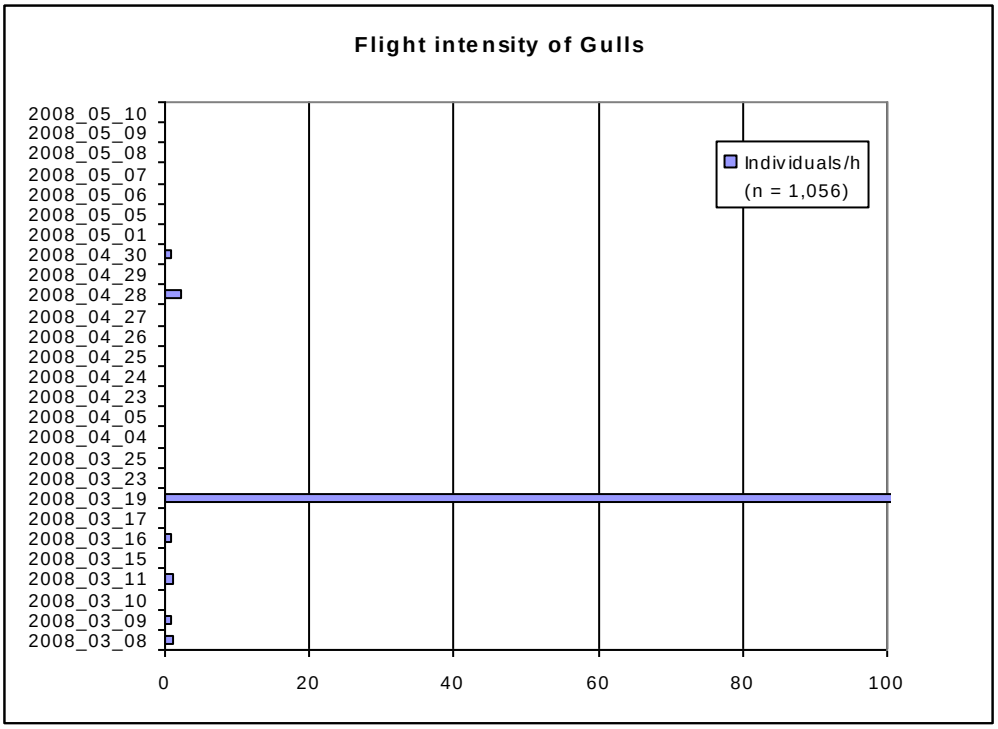

Figure 4-14. Flight intensity (individuals/h) of gulls recorded by visual observations at the observation point Blåvands Huk in spring 2008.

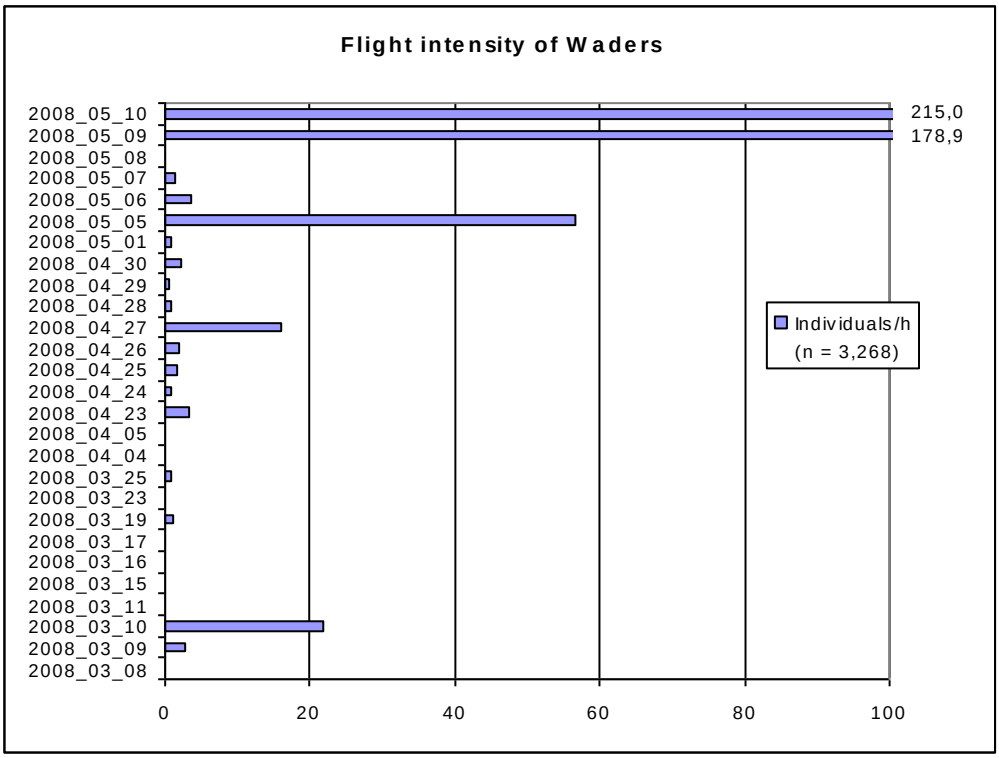

Figure 4-15. Flight intensity (individuals/h) of waders recorded by visual observations at the observation point Blåvands Huk in spring 2008.

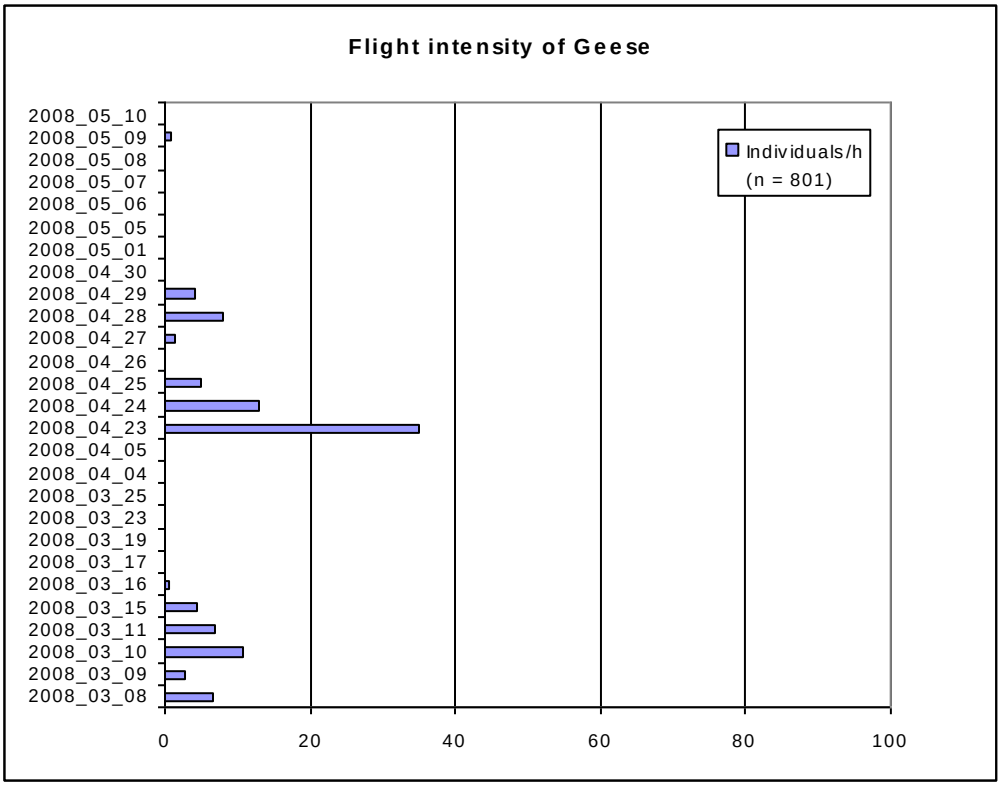

Figure 4-16. Flight intensity (individuals/h) of geese recorded by visual observations at the observation point Blåvands Huk in spring 2008.

4.3 Flight altitude

4.3.1 Ship-based investigations at Horns Rev

The flight altitudes for both anchoring positions Horns Rev I and Horns Rev II are shown in Figure 4-17.

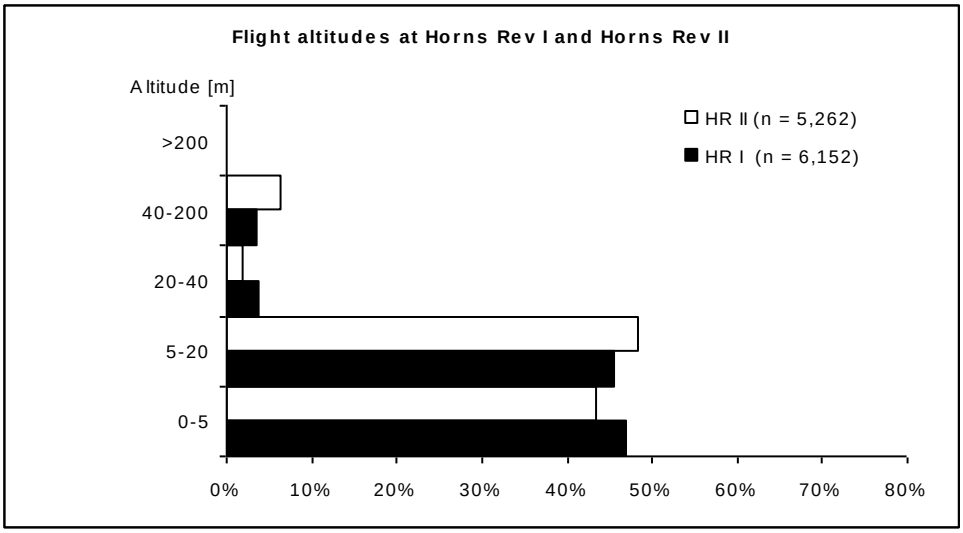

Figure 4-17. Altitude distribution (expressed as proportion of all observations) recorded by visual observations at the anchoring positions Horns Rev I (HR I) and Horns Rev II (HR II) in spring 2008.

Altitude distribution during daytime seemed to be rather regular at both offshore sites. No obvious differences between the wind farm (HR I) and the non-wind farm area (HR II) were apparent. At each site, about 92 % of all flight movements were recorded below 20 m. 7.4 % (HR I) and 8.1 % (HR II) of the birds were registered above 20 m.

4.3.2 Land-based investigations at Blåvands Huk

The flight altitudes recorded at the observation point Blåvands Huk are shown in Figure 4-18. Compared to the offshore sites more birds were recorded at altitudes between 40 and 200 m, and a comparably higher proportion of the migration was concentrated at very low altitudes (< 5 m). The higher proportion at medium altitudes is mainly due to the higher proportion of geese migrating at the coast, while the higher proportion of birds moving at low altitudes is due to movements of Common Scoter and waders.

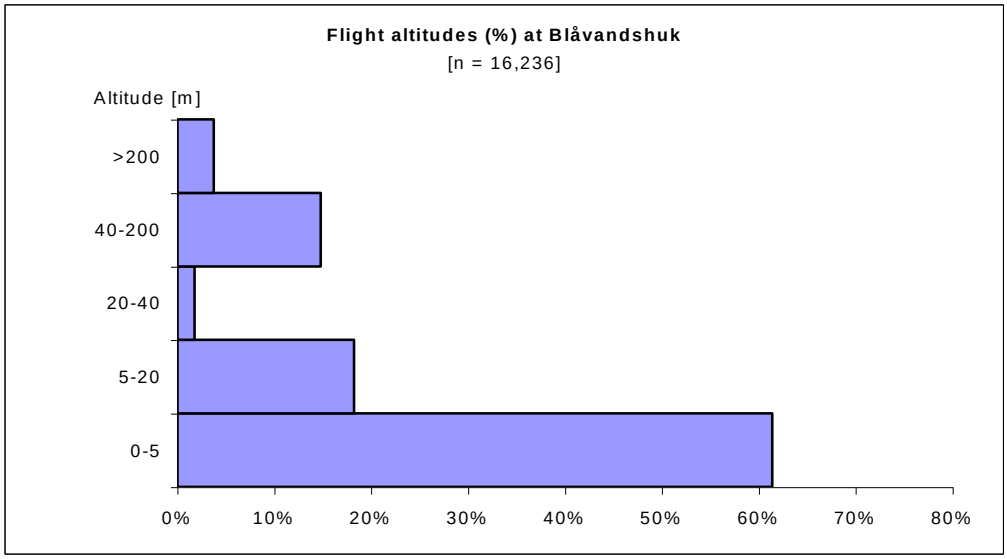

Figure 4-18. Altitude distribution (expressed as proportion of all observations) recorded by visual observations at the observation point Blåvands Huk in spring 2008.

4.4 Flight direction

4.4.1 Ship-based investigations at Horns Rev

The flight directions of all birds observed for both anchoring positions Horns Rev I and Horns Rev II are shown in Figure 4-19.

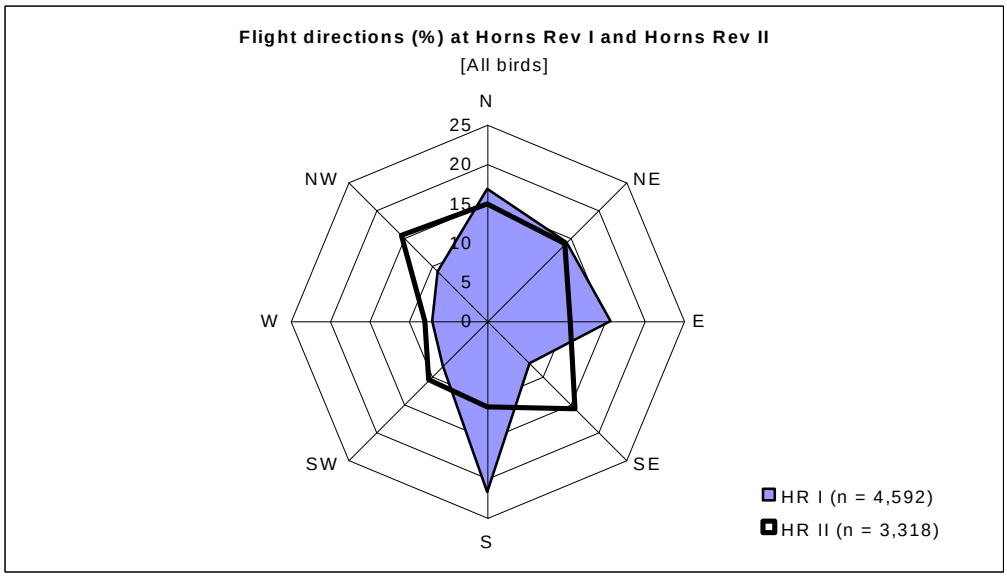

Figure 4-19. Flight directions of all birds observed (expressed as proportion of all observations) recorded by visual observations at the anchoring positions Horns Rev I (HR I) and Horns Rev II (HR II) in spring 2008.

Regarding all birds observed, neither at Horns Rev I nor at Horns Rev II a clear preference for a certain flight direction was observed. By contrast, regarding migrating birds only (i.e. songbirds, geese, waders, owls, birds of prey; see Figure 4-20), there was a clear preference for the expected flight directions north, north-east and east, which are typical for bird migrating during spring in Central Europe or over the North Sea. In general, the direction of migrating birds at HR2 OWF as compared to HR1 OWF was more oriented towards north than north-east and east.

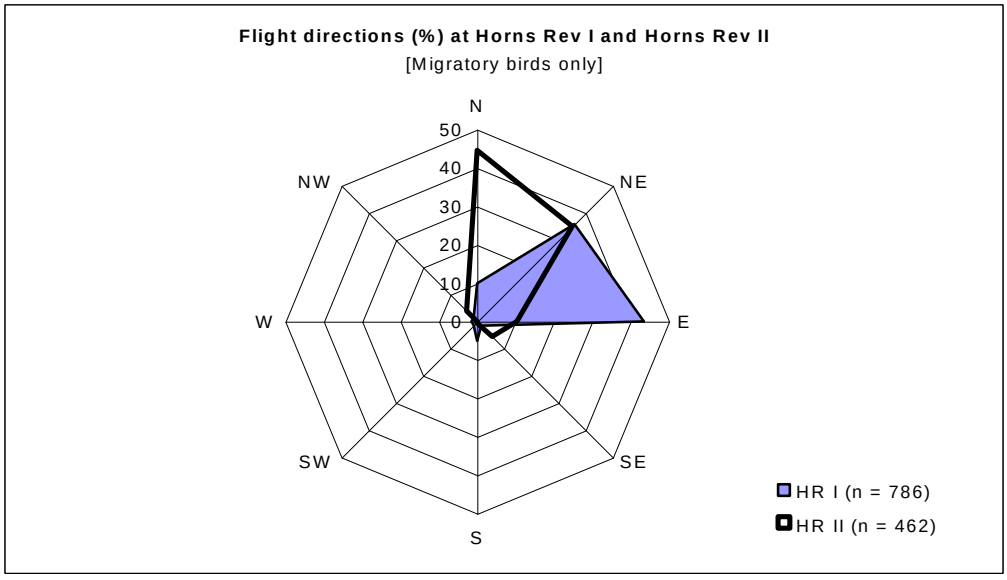

Figure 4-20. Flight directions of migratory birds only (expressed as proportion of all observations) recorded by visual observations at the anchoring positions Horns Rev I (HR I) and Horns Rev II (HR II) in spring 2008.

4.4.2 Land-based investigations at Blåvands Huk

The flight directions of all birds observed at the observation point Blåvands Huk are shown in Figure 4-21. Contrary to the direction of all birds at the offshore sites the observations at Blåvands Huk showed a clear preference for southward movements.

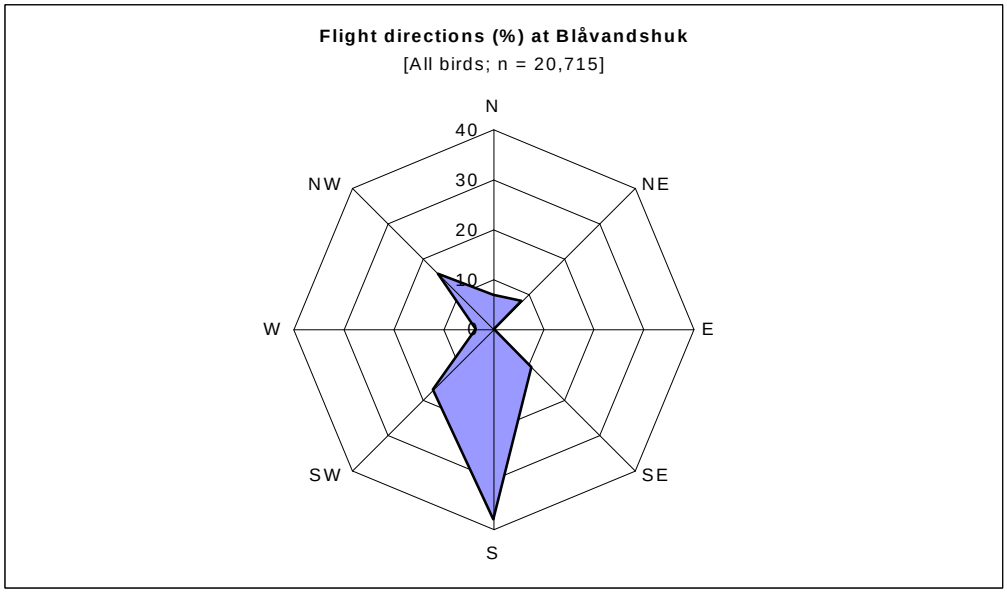

Figure 4-21. Flight directions of all birds observed (expressed as proportion of all observations) recorded by visual observations at the observation point Blåvands Huk in spring 2008.

4.5 Bird movements recorded by radar

4.5.1 Ship-based investigations at Horns Rev

During spring 2008, a total of 365 tracks were recorded at both anchoring positions Horns Rev I and Horns Rev II. In 76.9 % of the recordings it was not possible to determine species involved for the radar tracks. Probably in most cases these tracks may belong to flights of Sandwich Tern (*Sterna sandvicensis*). Species identification was obtained for 84 tracks (23.0 %) of 10 different species and species groups respectively (Table 4-3). At Horns Rev I, most records were of Common Scoter and Common Starling. At Horns Rev II, unidentified large gulls were recorded most frequently, with only a small numbers of other species.

Table 4-3: Identified species/species groups and number of birds/bird flocks during radar investigations at the anchoring positions Horns Rev I (HR I) and Horns Rev II (HR II) in spring 2008.

Species (lat.)	Species (engl.)	HR I	HR II
Gavia stellata	Red-Throated Diver	1	
Larus (magnus) sp.	Large gull indet.	24	216
Larus canus	Common Gull	3	3
Larus fuscus	Lesser Black-backed Gull	11	11
Larus marinus	Great Black-backed Gull	3	1
Larus ridibundus	Black-backed Gull	12	
Melanitta nigra	Common Scoter	321	35

Species (lat.)	Species (engl.)	HR I	HR II
Stercorarius parasiticus/pomarinus	Parasitic/Pomarin Skua	2	
Sterna sandvicensis	Sandwich Tern	34	3
Sturnus vulgaris	Common Starling	176	
Individuals		**587**	**269**

4.5.2 Land-based investigations at Blåvands Huk

During spring 2008, a total of 879 tracks were recorded at Blåvands Huk. In 49.8 % of the recordings it was not possible to determine species involved for the radar tracks. Species identification was obtained for 441 tracks (50.2 %) of three different species and species groups respectively (Table 4-4). The vast majority of the records were of Common Scoter followed by Red-throated Diver.

Table 4-4: Identified species/species groups and number of birds/bird flocks during radar investigations at the observation point Blåvands Huk in spring 2008.

Species (lat.)	Species (engl.)	Birds/Birds flocks
Gavia stellata	Red-Throated Diver	1,660
Melanitta nigra	Common Scoter	15,814
Sterna hirundo/paradisaea	Common/Arctic Tern	20
Individuals		**17,494**

Scoters at Horns Rev 1 OWF.

Figures 4-22 to 4-26 summarises the results of the profile analyses of bird movements between Blåvands Huk and the HR1 OWF. For each major group the results are split into number of flocks and number of individuals. Across all groups an overall trend is discerned with most flocks and individuals seen at distances shorter than 4 km from Blåvands Huk. Most of the waders and geese pass within 1 km distance, whereas divers and terns mainly pass at distances between 2 and 3 km from the coast. Common Scoters display a more complex profile, with large numbers of flocks seen from 0 to 4 km from the coast, whereas relatively few flocks involving large numbers of individuals were estimated at distances as far as 13 km from Blåvands Huk at the entrance to the HR1 OWF.

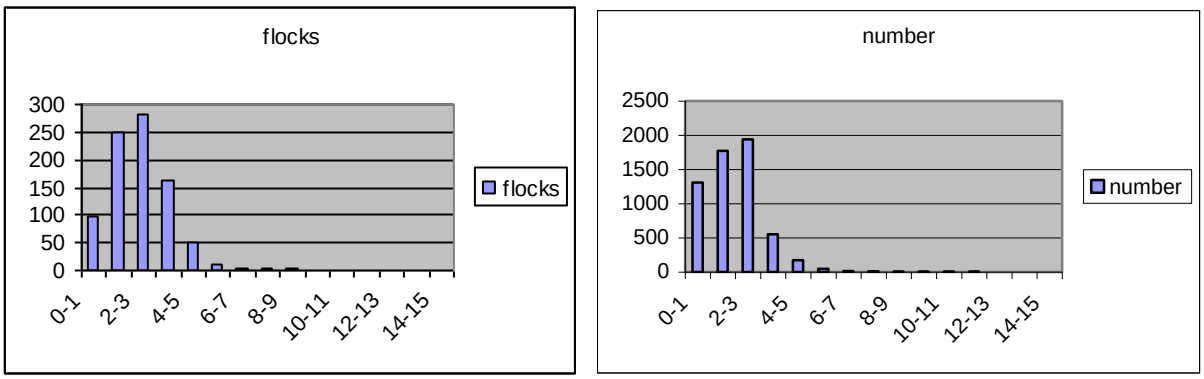

Figure 4-22. Variation in number of flocks (left) and estimated number of individuals (right) of Divers recorded at various distances from Blåvands Huk by radar observations. Y-axis gives number of flocks/individuals, while x-axis gives distance from Blåvands Huk in kilometres.

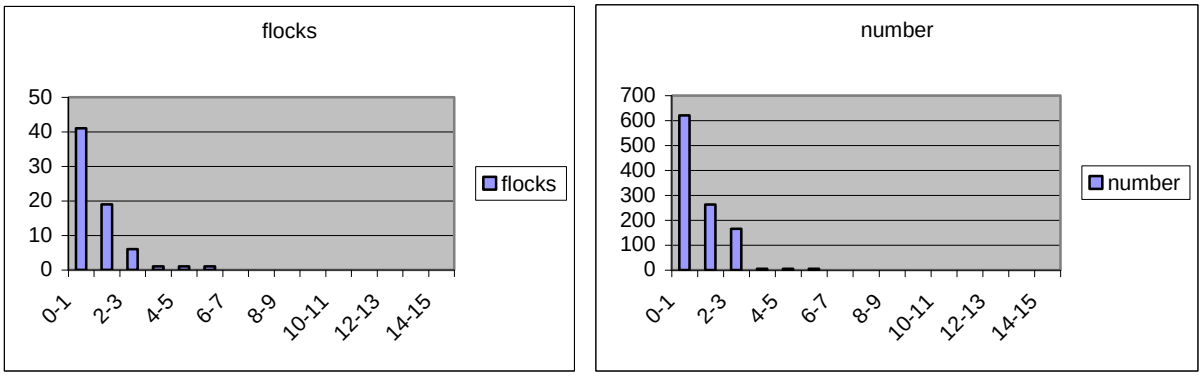

Figure 4-23. Variation in number of flocks (left) and estimated number of individuals (right) of Geese recorded at various distances from Blåvands Huk by radar observations. Y-axis gives number of flocks/individuals, while x-axis gives distance from Blåvands Huk in kilometres.

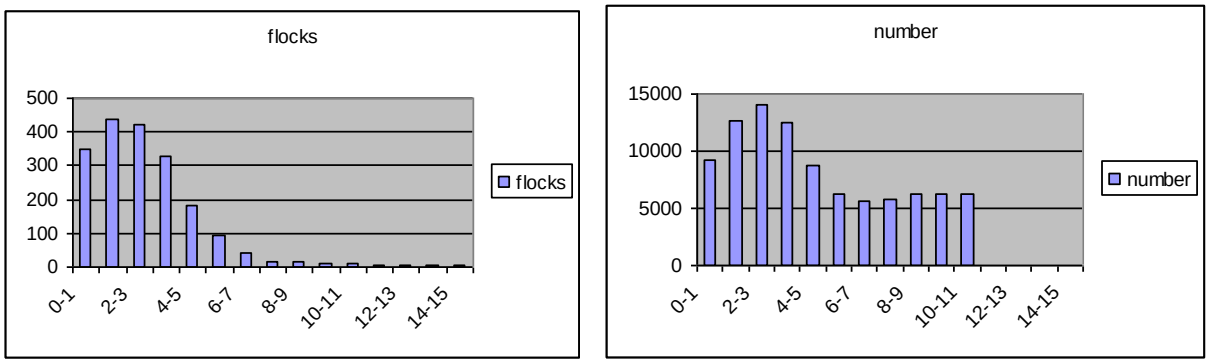

Figure 4-24. Variation in number of flocks (left) and estimated number of individuals (right) of Common Scoter recorded at various distances from Blåvands Huk by radar observations. Y-axis gives number of flocks/individuals, while x-axis gives distance from Blåvands Huk in kilometres.

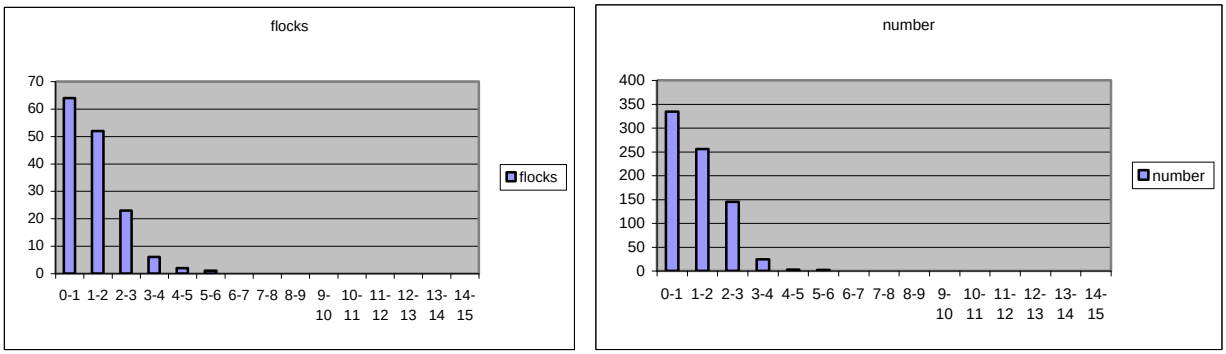

Figure 4-25. Variation in number of flocks (panel above) and estimated number of individuals (panel below) of Waders recorded at various distances from Blåvands Huk by radar observations in spring 2008. Y-axis gives number of flocks/individuals, while x-axis gives distance from Blåvands Huk in kilometres.

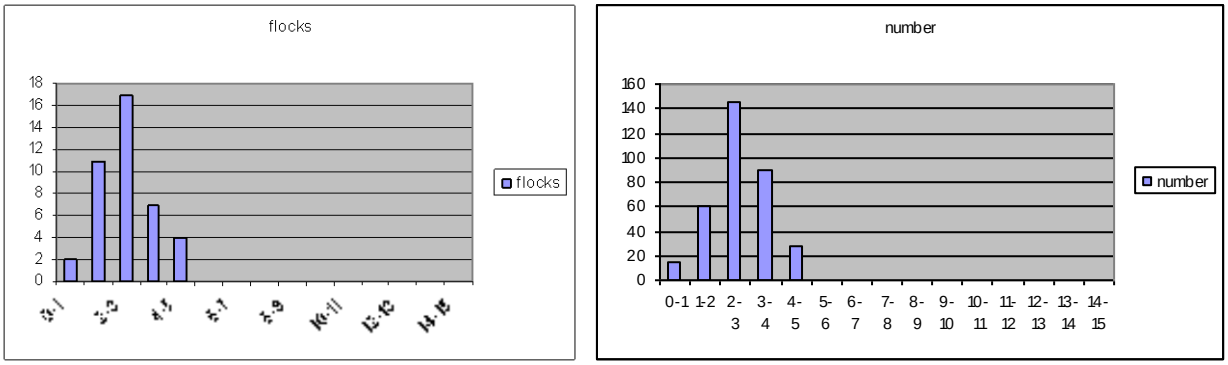

Figure 4-26. Variation in number of flocks (left) and estimated number of individuals (right) of Terns recorded at various distances from Blåvands Huk by radar observations in spring 2008. Y-axis gives number of flocks/individuals, while x-axis gives distance from Blåvands Huk in kilometres.

4.6 Response of bird migration and movements to the Horns Rev 1 offshore wind farm

As described in chapter 4.1.1 hardly any migration was recorded at the HR1 OWF, and most radar observations consisted of local feeding or resting movements. Although some movements of Common Scoters were recorded here, they only involved few flocks. Most bird movements near Horns Rev 1 were feeding Sandwich Terns which undertook localised movements (see examples Figure 4-27). Hence, no response to the HR1 OWF could be observed.

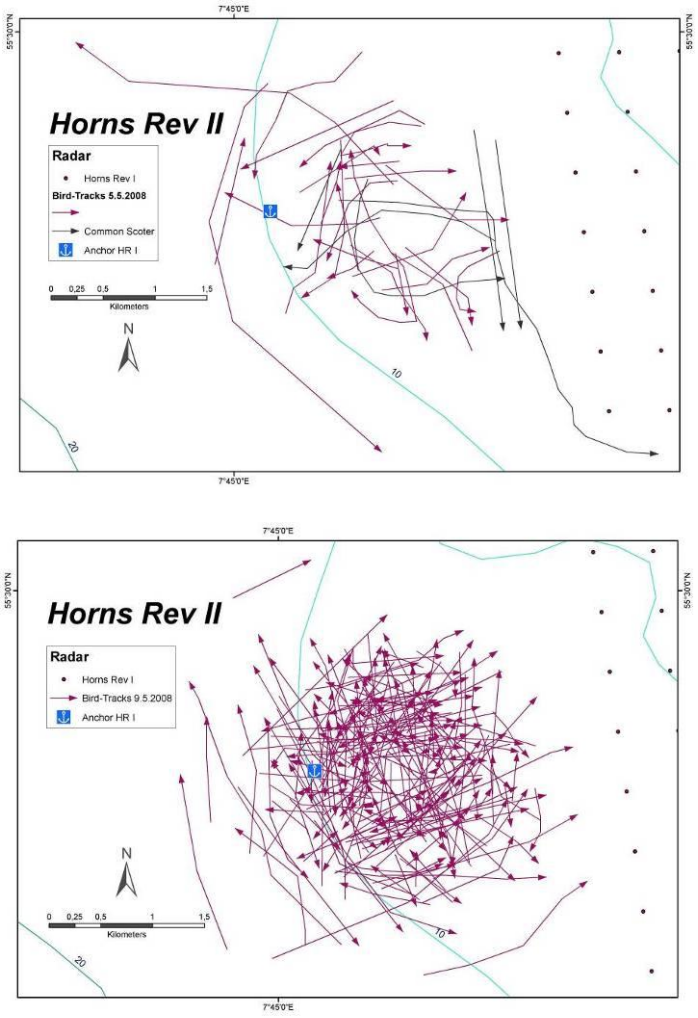

Figure 4-27. Example of localised feeding movements of Sandwich Terns (red arrows) and Common Scoter (black arrows) recorded just west of the HR1 OWF on the 5th and 9th of May.

4.7 BACI design for monitoring programme

A classic BACI design (ANOVA area-time factorial design) will be applied to radar recordings (direction and density of echoes) testing effects of year, treatment (pre-construction and post construction) and block using impact blocks covering the wind farm foot print areas and adjacent impact zones and control blocks. During the PSO monitoring programme at the HR1 OWF (2003-2005) 15 transects located parallel to the most northern and eastern row of turbines were used to test lateral displacement effects to a distance of 7 km from the wind farm. Due to the blind angle of the radar located on HR1 birds approaching the wind farm from the south and east could generally

not be tracked efficiently. Effects on flight orientation of day-time migrants were documented at distances of up to 2 km from the wind farm. In the Horns Rev 2 monitoring programme it is recommended to design comparisons of before/after construction scenarios for freely chosen areas around the two wind farms, as all radar recordings will be stored in a raster GIS. The impact and control sites can then be selected to maximise the use of obtained recordings for the entire Horns Rev area, including the data obtained during the PSO monitoring programme.

Black-Throated Diver

Scoters at Horns Rev 1 OWF.

5 DISCUSSION AND CONCLUSIONS

5.1 Baseline results

5.1.1 Species composition

At both offshore sites movements of birds were dominated by ducks, terns and gulls with Common Scoter, Herring Gull, Lesser Black-backed Gull, Common Gull and Sandwich Tern being numerically the most important species. This is much in agreement with the results of the baseline monitoring of resting birds carried out during the same period (Skov et al. 2008). The movements of these species/species groups were most likely feeding movements, while migratory movements were estimated to comprise less than 20 % of the total number of records over Horns Rev. Divers were observed more frequently at HR2, and Common Scoters less frequently as compared to HR1. The difference in numbers of flying divers is corroborated by the results of the aerial survey programme, which revealed higher densities at HR2 than HR1 OWF's. The difference in numbers of flying scoters, however, is not reflected in the results from the aerial surveys, but it may be explained by movements of birds between the main feeding area east of HR1 OWF and smaller feeding areas near or within HR2 OWF (Skov et al. 2008).

The vast majority of the observations at the coast were of typical coastal water birds, whereas no songbirds were seen. The three most abundant species at Blåvands Huk were Common Scoter (62 %), Knots (14 %) and divers (4 %). The species composition and phenology of the bird migration is described in more detail in the review by Jacobsen (2008). The results from this study are generally in good agreement with this review.

As a result of the dominance of scoters, terns and gulls the altitudinal distribution of flights displayed a concentration at altitudes lower than 20 m. At Blåvands Huk, due to the migration of geese, a moderate proportion of birds was observed at altitudes between 40 and 200 m.

5.1.2 Variation of bird migration recorded at Horns Rev and Blåvands Huk

The study revealed low flight intensity over Horns Rev and hardly any migration activity during daylight hours – most birds being local displayed feeding movements in all directions. Between HR1 OWF and Blåvands Huk profile analyses showed a steep increase in flight intensities when approaching the coast at Blåvand. In general, flight intensities were much higher both for migration and feeding movements near the coast than off-shore, with some species like divers peaking just a few kilometres offshore, whereas others like waders peaked at the coastline. This study is the first to describe patterns of variation in the intensity of bird migration and movements as a function of distance from the coast in this part of the North Sea. It should be underlined, however, that the detection of birds by the radar on Blåvands Huk has a distance bias which is unknown, and hence the results of the profile analyses should only be used as a rough indication of actual intensities of movements. The movements of birds at Blåvands Huk

were dominated by southward movements of waterbirds compensating for northward drift by the current during the night. These compensation movements are described by Meltofte & Kiørboe (1973) and Petersen (1974) and again by Petersen et al. (2006), and typically involve local feeding birds which move southwards during the first morning hours.

The bird migration study indicated that movements driven by local and in most cases moderate feeding concentrations are more important on Horns Rev in spring, while close to Blåvand compensating movements of Common Scoters are more important. The low intensity of bird movements and migration during spring indicate that potential barrier effects of the two wind farms on long-distance migrants most likely are of limited magnitude during this season. However, the profile analyses of the radar data from Blåvand indicate that larger movements of Common Scoters occur irregularly offshore, and the aerial surveys over the past five years have shown that a larger proportion of the scoters in the area may concentrate over the western part of the reef, especially during late winter (Petersen et al. 2006). It should be noted that the potential for barrier effects on long-distance migrants may be larger during autumn migration due to the much higher volume of birds passing through the area during autumn as compared to during spring.

5.1.3 Response of bird migration to the Horns Rev 1 offshore wind farm

No response behaviour of flying birds to the HR1 OWF could be established due to the low flight intensity at the site and lack of near-by feeding concentrations of Common Scoter. In addition, the use of ship-based radar shortened the effective detection range limiting the scope for tracking behavioural changes of birds passing the wind farm.

5.2 Monitoring design

The baseline monitoring of bird migration for the HR2 OWF provided useful information which supplement the existing knowledge and data obtained during the PSO monitoring programme, especially in relation to spring migration through the corridor between the Danish west coast at Blåvands Huk and HR1 OWF. However, due to the necessary change in the monitoring design and timing (from fixed to ship-based radar installation, lack of coverage in autumn) on account of the postponement of the construction works at HR2 the amount and quality of the data obtained were less than originally envisaged. As the data on bird migration collected during the PSO programme did not cover the central and western areas of Horns Rev the cumulative database on bird migration across Horns Rev is judged insufficient for the baseline of the HR2 monitoring programme.

For this reason the baseline has been extended into the autumn season using the established foundations in the HR2 OWF as platforms for continuous recordings using 25 kW radars concurrently with recordings from the HR1 transformer station and from the coast at Blåvands Huk.

5.3 Conclusions

The monitoring programme on bird migration associated with the construction of the HR2 OWF is focused on documenting the long-distance migration across and along Horns Rev during autumn and spring as a basis for assessing impacts of HR2 as well as cumulative effects of both wind farms in the area. The migration study provided useful information which supplements the existing knowledge and data obtained during the PSO monitoring programme, especially in relation to spring migration through the corridor between the Danish west coast at Blåvands Huk and HR1 OWF. However, due to the necessary change in the monitoring design and timing (from fixed to ship-based radar installation, lack of coverage in autumn) on account of the postponement of the construction works at HR2 the amount and quality of the data obtained were less than originally envisaged. As the data on bird migration collected during the PSO programme did not cover the central and western areas of Horns Rev the cumulative database on bird migration across Horns Rev is judged insufficient for the baseline of the HR2 monitoring programme.

A classic BACI design (ANOVA area-time factorial design) will be applied to radar recordings (direction and density of echoes) testing effects of year, treatment (pre-construction and post construction) and block using impact blocks covering the wind farm foot print areas and adjacent impact zones and control blocks. As all radar recordings will be stored in a raster GIS comparisons of before/after construction scenarios can be made for freely chosen areas around the two wind farms. The impact and control sites will be selected to maximise the use of obtained recordings for the entire Horns Rev area, including the data obtained during the PSO monitoring programme.

The study showed that movements of birds over the offshore areas of Horns Rev were dominated by foraging flights or flights of resting birds, especially of Common Scoter, Herring Gull, Lesser Black-backed Gull, Common Gull and Sandwich Tern. Hardly any migration activity was recorded over the reef during daylight hours. Between HR1 OWF and Blåvands Huk profile analyses showed a steep increase in flight intensities when approaching the coast at Blåvand. In general, flight intensities were much higher both for migration and feeding movements near the coast than offshore. Divers were observed more frequently at HR2, and Common Scoters less frequently as compared to HR1. The vast majority of the observations at the coast were of typical coastal waterbirds, whereas no songbirds were seen. The movements of waterbirds here were dominated by southward movements of birds compensating for northward drift by the current during the night. As a result of the dominance of scoters, terns and gulls the altitudinal distribution of flights displayed a concentration at altitudes lower than 20 m.

No response behaviour to HR1 OWF could be established due to the low flight intensity at the site and lack of feeding concentrations of Common Scoter. In addition, the use of ship-based radar shortened the effective detection range limiting the scope for tracking behavioural changes of birds passing the wind farm.

The low intensity of bird movements and migration during spring indicate that potential barrier effects of the two wind farms on long-distance migrants in general are limited during this season. However, the profile analyses of the radar data from Blåvand indicate that larger movements of Common Scoters occur irregularly offshore, and the aerial surveys over the past five years have shown that a larger proportion of the scoters in

the area may concentrate over the western part of the reef, especially during late winter. Thus, it cannot be ruled out that periodic barrier effects take place in relation to local feeding movements. It should also be noted that the potential for barrier effects on long-distance migrants may be larger during autumn migration due to the much higher volume of birds passing through the area during autumn as compared to during spring. As the data on bird migration collected during the PSO programme did not cover the central and western areas of Horns Rev the cumulative database on bird migration across Horns Rev is judged insufficient for the baseline of the HR2 monitoring programme. For this reason the baseline has been extended into the autumn season 2008 using the established foundations in the HR2 OWF as platforms for continuous recordings using 25 kW radars concurrently with recordings from the HR1 transformer station and from the coast at Blåvands Huk.

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