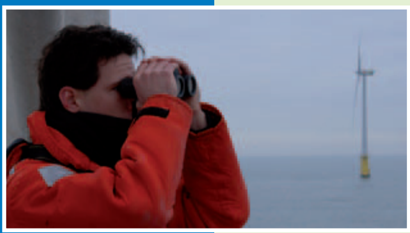
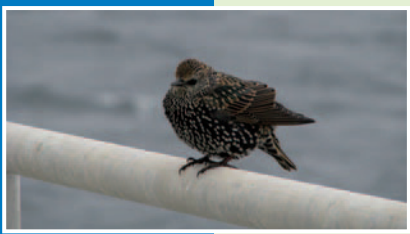
Effect studies Offshore Wind Farm Egmond aan Zee

Progress report on fluxes and behaviour of flying birds





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NoordzeeWind

NUON

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observer recording flight path of bird through wind farm (© R.Fijn);
migrating starling resting on metmast (© K.Krijgsveld);
research fishing vessel with associated gulls (© M.Poot).

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Preface

'NoordzeeWind' (a joint venture of Nuon Duurzame Energie and Shell Wind Energy) has built a wind farm consisting of 36 wind turbines off the coast of the Netherlands, near Egmond aan Zee. The turbines were built in the summer of 2006 and the site is in operation since January 2007. The main goal of this wind farm has been to evaluate the economical, technical, ecological and social effects of offshore wind farms in general. Therefore a Monitoring and Evaluation Program (NSW-MEP) has been developed to gather the knowledge resulting from this project. This knowledge will be made available to all parties involved in the realisation of large-scale offshore wind farms. Bureau Waardenburg and IMARES in cooperation have been commissioned to execute both the baseline and the effect study on the effects the wind farm has on flight paths, flight altitudes and flux of local and migrating marine birds as well as non-marine migrating birds.

The baseline study, that describes the reference situation before construction of the wind farm, has been carried out in 2003-2005, and results for flying birds are reported (Dirksen *et al.* 2005; Krijgsveld *et al.* 2005). In the Strategy of Approach (Krijgsveld *et al.* 2006) the study design of the second part of the monitoring and evaluation program – the effect study – is presented, including the general set up of the study and the techniques that are employed.

The report at hand is a status report presenting data on flying birds that were collected during the first part of this study. Data are based on radar observations as well as visual observations, both carried out in the wind farm area. The data presented here are from preliminary analyses of data collected from the start of the program in March 2007 until October 2007. In the final report, planned in 2009, results of the entire two-year monitoring programme will be presented and evaluated.

Table of contents

1 Introduction

1.1 Background

Offshore Wind farm Egmond aan Zee

Wind power is one of the most important and promising forms of renewable energy, and significant growth is projected for the coming years. Offshore wind farms are an attractive alternative to onshore wind turbines, especially in densely populated countries like the Netherlands. Positive effects of offshore wind farms are mainly economical and social related, but benefit is gained also for mitigating global climate change by increasing the amount of sustainable energy. Negative impacts of offshore wind farms are effects on the surroundings in terms of visual pollution, noise emission and direct impact on nature. In order to increase the supply of renewable energy in the Netherlands, the Dutch government has decided to support the construction of the OWEZ near shore wind farm, consisting of 36 turbines ca. 8-18 km off the coast of Egmond aan Zee in the Netherlands.

Monitoring and Evaluation Program

This project has been granted to 'NoordzeeWind' (Nuon Duurzame Energie and Shell Wind Energy). Starting in the summer of 2006 the wind turbines were built and the site is in operation since January 2007. The project serves as a demonstration project to build up knowledge and experience with the construction and exploitation of large-scale offshore wind farms. To collect this knowledge, an extensive Monitoring and Evaluation Program (NSW-MEP) has been designed in which the economical, technical, ecological and social effects of the OWEZ are gathered. The study on flying birds concerns the ecological effects of the wind farm on flying birds. Effects studied comprise flight paths, flight altitudes and flux of local and migrating seabirds as well as non-marine migrating birds. The report at hand describes a phase of this study.

Effects on flying birds

To be able to assess the effects of the wind farm on flying birds, flight patterns have been recorded in the 'reference situation', *i.e.* the situation without wind turbines. This baseline study has been carried out in 2003-2004, and results on flying birds are presented in (Dirksen *et al.* 2005; Krijgsveld *et al.* 2005). Data from the closely related project on locally foraging birds in a larger area around the wind farm are presented in (Leopold *et al.* 2004a; Leopold *et al.* 2004b).

This report

The report at hand is an interim report and describes the first results of the effect study as observed during the period after construction of the wind farm. The data that were analysed cover the period from March through October 2007. Especially the data from radar require time to process and analyse, and for consistency in the report it was chosen to cover the same time span for all the different observation techniques. This explains why no data beyond October are included in this report. This interim status report shows the first preliminary results of fluxes, flight paths and flight altitudes of birds in the OWEZ area, and includes some discussion about the influence of the OWEZ offshore wind farm on flying birds, as results suggest thus far.

Observations will continue through 2008, resulting in a final report in which data recorded through the entire effect study will be analysed and presented, and compared to the baseline study. These results will allow an assessment of potential disturbance, barrier effects and collision risks of wind turbines in the coastal waters of the Dutch North Sea.

1.2 Study aims

Types of effects

Derived from land-based studies, the NSW-MEP requires bird research to enable an analysis of three types of possible effects of wind farms on birds: collisions of flying birds with turbines or their wake, disturbance of flight paths, or barrier effects, and disturbance of locally resting and/or feeding birds.

Studying flight patterns

To determine what effects the OWEZ wind farm has on birds, the aim is to quantify the following aspects of flight patterns of both local and migrating marine birds as well as non-marine migrating birds in the area:

- fluxes of flying birds (*i.e.* intensity; number of birds per time unit per surface area);
- flight paths of flying birds;
- altitudes of flying birds.

Flight patterns in relation to the wind farm are being quantified by using a combination of automated and visual observation techniques. From the metmast in the area, visual observations during fieldwork days are being carried out, as well as radar observations with both a vertical radar and a horizontal radar. Visual observations give insight in species composition and species distribution in the area, as well as species-specific information on flight patterns. Radar observations are being carried out around the clock, each day, all year, and thus give insight in overall flight patterns in the area.

Species of interest

Targeted species of interest are:

- local seabirds (such as divers, guillemots and auks);
- migrating seabirds (such as divers and scoters);
- migrating non-marine birds (such as thrushes and geese).

All groups are at risk of the three potential negative effects of wind farms (collision, disturbance, barrier effects). Marine birds are of interest within the framework of this study as seabirds are generally long-lived birds with a low reproduction and are therefore vulnerable to disturbance from the surroundings. The OWEZ wind farm is located close by wintering areas of international importance for seabirds like red-throated diver and common scoter. Migrating marine and non-marine birds are vulnerable as they fly partly at altitudes with an immediate risk of collision and of disturbance of flight paths. Migration mainly takes place during the night, when the risk of collision is increased due to lower visibility (Poot & Lensink 2007).

Research questions

The research questions for the study can be summarised as:

- What are fluxes, flight paths and flight altitudes of the species of birds that occur in the OWEZ wind farm area, 10-18 km off the Dutch coast?
- How do fluxes, flight altitudes and flight paths vary between seasons, spring and autumn migration, day and night, and under varying weather conditions?
- Are these fluxes, flight altitudes and flight paths influenced by the presence of the offshore wind turbines in the OWEZ area?

1.4 Outline of chapters

Following this introduction, materials and methods are briefly described in chapter 2. In chapter 3, data are presented on the effectiveness of Merlin radar data that have been collected, shown through calibration results. The next three chapters (4-6) give an overview of the results obtained thus far. In chapter 4, results are described that were obtained on fluxes, or flight intensities, of birds in the wind farm area. In chapter 5 results on flight paths are presented, and in chapter 6 results on flight altitudes are presented. Results are discussed in chapter 7, together with prospects for the second and final year of the effect study (2008).

2 Materials and methods

To assess the flight paths of birds in the area of the wind farm, visual observations as well as fully automated radar observations and registration of birdcalls are being carried out from the metmast in the OWEZ wind farm area. Methodological information can be found in the following paragraphs:

- In §2.1 we give an overview of the location of the wind farm and the position of the turbines and the metmast.
- In §2.2 we give an overview of the days on which visual observations were carried out, along with the weather conditions.
- In §2.3 and §2.4 we describe the various methods that are used to collect the desired information. In §2.3, we describe the visual observations. These include panorama scans, counts of flight activity in versus outside the wind farm as well as following flight paths of individual birds.
- Radar observations, described in §2.4 & §2.5, include a vertically and a horizontally turning radar, that collect data continuously through an automated detection system called Merlin, which is developed and supplied by DeTect Inc. (Florida, USA).
- Nocturnal bird calls are being collected during migratory periods, to gain insight in the species composition migrating through the area. This technique is being developed and is not presented in this interim report, but data will be presented in the final report (2009; see also §2.3.4).

2.1 Study area

The OWEZ wind farm is positioned between 8 and 18 km off the Dutch coast near Egmond aan Zee (fig. 2.1). It consists of 36 Vestas V90 turbines. Hub height of the turbines is 70 m above mean sea level, rotor diameter is 90 m. Maximum altitude of the rotors therefore is 115 m, minimum altitude 25 m.

All observations in this study are being carried out from a meteorological mast (metmast; fig. 2.2). The mast is positioned at a distance of 500 m from the nearest turbines, south of the wind farm.

The metmast was reached in either of two ways. First, from IJmuiden harbour using ships hired by the Bouwcombinatie Egmond (BCE), on combined sails with people doing maintenance on turbines. Second, from IJmuiden harbour using a Rigid Inflatable Boat of Distel Sail. The latter option was used most frequently, as fieldwork started half an hour before sunrise and ended half an hour after sunset.

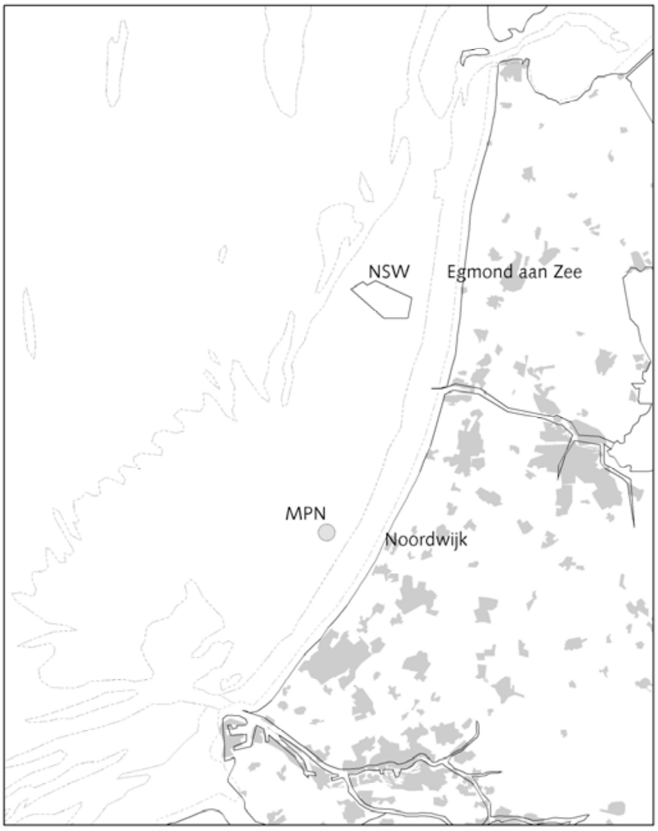

Figure 2.1 Location of the OWEZ wind farm (NSW), as well as of the observation platform 'Meetpost Noordwijk' (MpN) that was used for the baseline study.

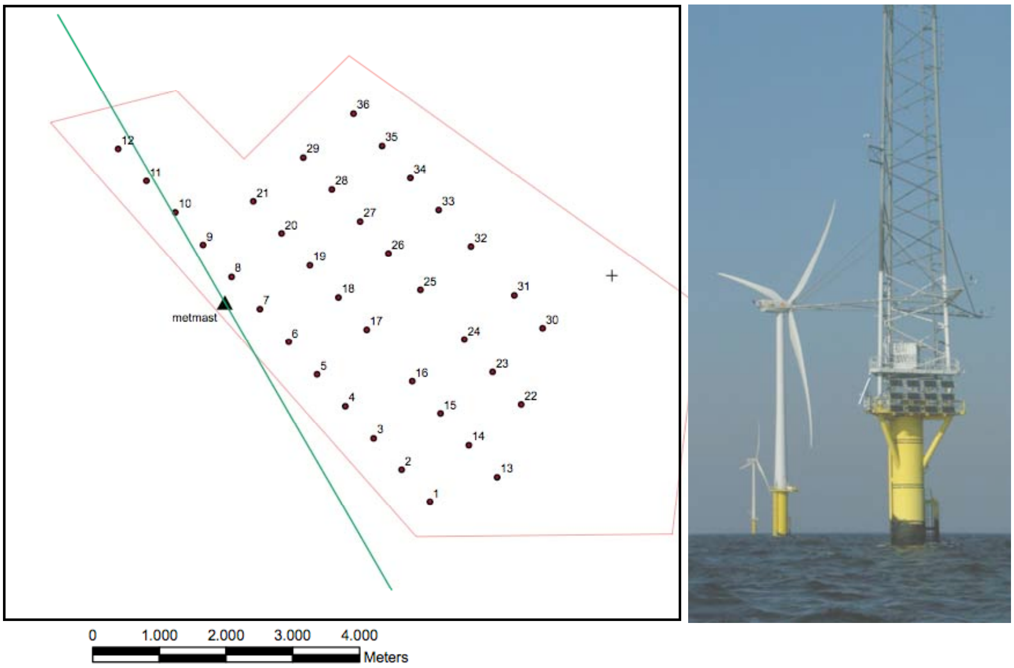

Figure 2.2 Outline of the wind farm with the position of the metmast (triangle) as well as orientation of the vertical radar (green line; beam does not reach beyond turbines 10 and 5 in reality). Photograph shows the metmast from the south and three wind turbines (Photo: K. Krijgsveld).

2.2 Overview of observation days

Visual observations

The study period reported here covers the start of the effect study in February 2007 until the end of October 2007. In this period, visual data were collected on a total of 18 observation days. An overview of these observation dates is given in table 2.4, which includes also the weather conditions on these dates.

Table 2.4 Overview of observation days in the reported period (February-October 2007). Shown are dates, wind direction, wind force (Bft), significant wave height (cm), visibility (km), ambient temperature (T_a, °C) and clouds/precipitation.

date	remarks	weather conditions					
		wind dir	force Bft	waves cm	visibility km	T_a	clouds/rain
Winter							
Feb 21	start-up/installation	SSW	3-4	50-90	3	10	cloudy, rain
Spring							
Mar15	start-up/installation	SW	4	60	5	10	clear, dry
Mar26	start-up/installation	E	4		5	10	clear, dry
Apr 5		W	3		>10	12	partly cloudy, dry
Apr 12		N	3	80	>10	15	clear, dry
May25		S	1	30	>10	20	partly cloudy, dry
Summer							
Jun 5	maintenance	NE	5	90			dry
Jun 21	1/2 day; thunderstorm	VAR	3	50	>25	18	partly cloudy, dry
Aug 2		NW	4	60	>10	18	partly cloudy, dry
Aug20		SSE-NNE	1-4		>15	18	cloudy, few showers
Autumn							
Sep 6		NW	4	90	>10	16	cloudy, dry
Sep 13		NE-SE	3-1	70	>10	17	cloudy, dry
Oct 2	night	E	3-2		-		cloudy, dry
Oct 3		E	4-2	60	2	12	cloudy, showers
Oct 10		NE	2-4		4	15	fog / clear
Oct 25		NE	4		5	10	cloudy, dry
Nov 2		NW	3-2		4-1,5	13	fog, afternoon rain

total number of observation days in period February – October 2007: 15

Radar observations

The radars were installed on the metmast late January 2007. Initial data collection could be started on February 23 2007. Remotely controlling the radars (switching from transmit mode to stand-by mode and *vice versa* from the BuWa-office) was first accomplished early in March 2007. March and most of April were spent to evaluate the

Merlin-settings; and adjusting these gradually to improve the detection of birds by Merlin.

End of April the **X-band vertical radar** broke down, and could not be repaired until mid June. Since then, the X-band has been running more or less continuously. Only during strong winds (>7 Bft) the X-band is turned off remotely to prevent damage to e.g., the gear box (see §2.3.3 for detailed overview of operation times).

The **S-band horizontal radar** has been running since the end of April 2007. It is remotely turned off at gale force winds (>8 Bft). A settings change for the S-band was effected on October 22 2007, as a result of validation and calibration test. The result of this change was an increase in the percentage of bird tracks that were recorded by Merlin. Because processing and analysis of the radar data is time consuming, radar data for this reporting period are analysed up to that moment. For reasons of consistency, all other types of observations are analysed up to the same moment.

2.3 Visual observation methods

2.3.1 Panorama scans

A panorama scan is a visual count of all birds flying within sight of the observation platform (Lensink *et al.* 2000). It serves as a backup and calibration of the radar counts, and supplies us with information on species composition, density, flight altitude and flight direction of birds around the platform. The technique has been calibrated extensively (Lensink *et al.* 1998; Poot *et al.* 2000).

A panorama scan was done by scanning the air and water in a 360° circle around the platform, using a standard pair of 10*42 binoculars fixed on a tripod. The 360° circle was divided into 8 sectors (fig. 2.3), to be able to register where the bird was flying (e.g., NW or SE). Each panorama scan consisted of two full circles, one to count birds at or just above sea level (low scan, 1/2; horizon in the middle of the field of view of a pair of binoculars), and a second to count birds at higher altitudes (high scan, 1/8: horizon at an eighth of the field of view). A panorama scan was carried out every hour (during daylight). Of all birds flying through the field of view of the binoculars, species, number, altitude (4 classes), distance (in 4 classes; fig. 2.4) and behaviour (following ESAS coding, (Camphuysen & Garthe 2001)) was recorded. Recording was done on preprinted forms.

The panorama scan is in its essence comparable to a radar; by slowly moving the binoculars in one direction, the observer scans the air in view for flying birds and birds floating on the sea surface. If the density of flying birds is expressed as density per scan, the data of the panorama scan are comparable with those of the horizontal radar.

In this report, data are presented covering the field work carried out between the start of the project in February, through to the end of October 2007. Results are given in densities of birds per scan (number per unit surface area). Because distance and altitude of each bird was recorded, these numbers could be transformed to number of birds per km^2. The furthest distance class includes all distances over 3 km, and bird numbers cannot be transformed to densities per surface area. Also, at distances over 3 km, more birds are being missed because of the large distance, especially under poorer visibility. For this reason, only birds flying within 3 km distance were included in the analysis. The analysis carried out for the report at hand focuses on flight paths rather than locally active birds. Birds sitting on the water are covered in the research program carried out by Imares (Leopold & Camphuysen 2008). These birds form a separate group which should be considered separately rather being included in the main data set on fliying birds. For these reasons, locally active birds (without distinct direction) and birds sitting on the water were excluded from the analysis for this report. In the final report, when more data are available, the data can be analysed in more detail and the information on local birds will be presented as well.

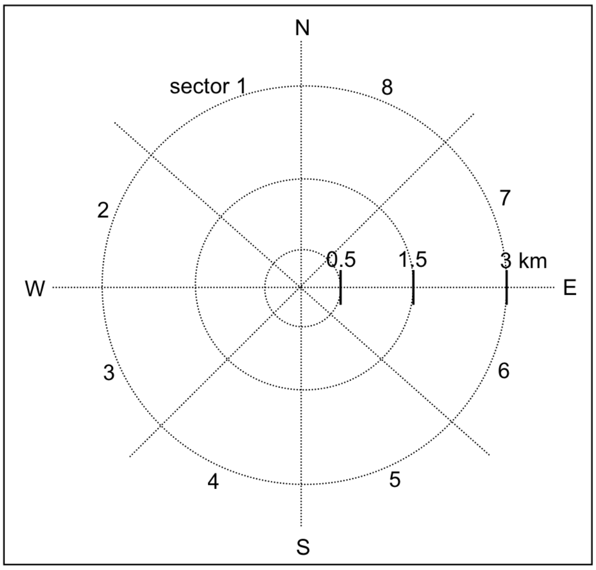

Figure 2.3 Schematic view of the panorama scans with the division into sectors and distances. The metmast, as observation platform, is situated in the centre. Surface area of distance 0-0,5km=0,79km², of 0,5-1,5km=6,28 km², of 1,5-3km=21,21km². For scan altitudes see fig. 2.4.

Observer carrying out a panorama scan, counting birds in sector 4 or SW. Photo: H. Prinsen

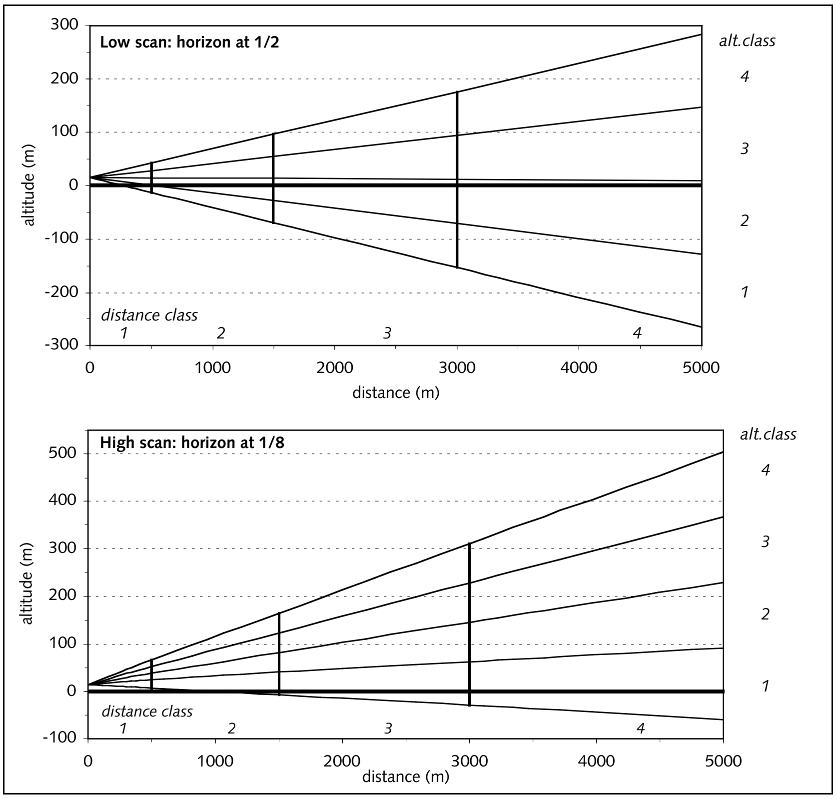

Figure 2.4 Schematic view of the volume of air covered with panorama scans. Scans were performed at two altitudes: a low scan with the horizon halfway the binocular view and a high scan with the horizon at 1/8 in the lower part of the binocular view. With the sea surface visible in the bottom part of the view, maximum altitude at which birds are scanned is 165 m at 1500 m distance.

2.3.2 Flight activity within versus outside wind farm

To measure differences in flight activity of various bird species flying in the wind farm area, the number of birds flying through a transect line both within and outside the wind farm was counted (fig. 2.5). Each transect was observed with a pair of binoculars for 5 minutes. The two transects were observed alternately (so-called paired observations), to prevent observer differences and differences in timing and frequency of observations.

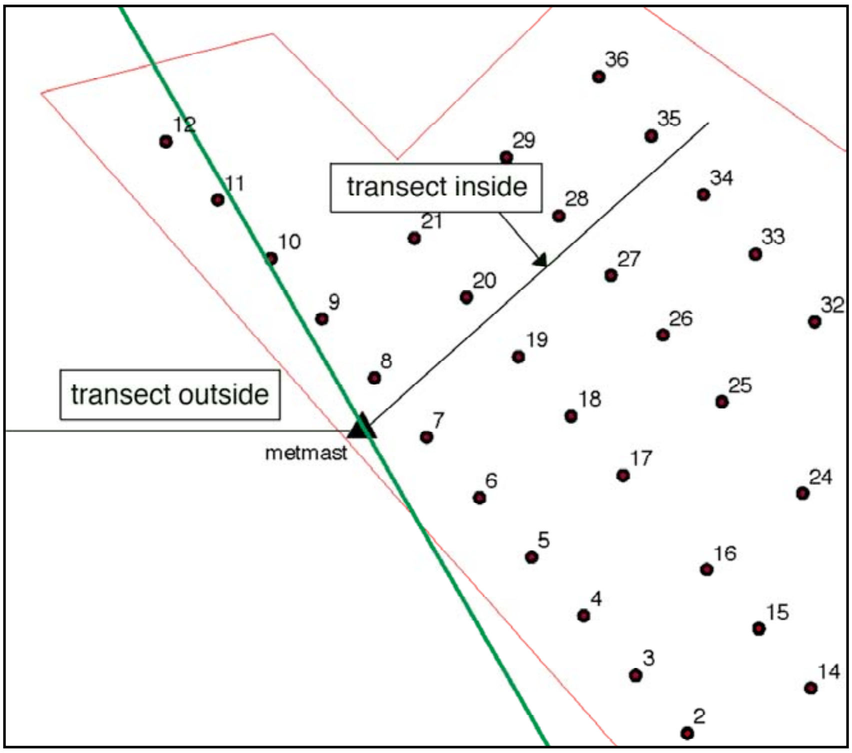

Figure 2.5 Schematic view of the orientation of the transect lines inside and outside the wind farm.

2.3.3 Bird tracks through the wind farm

During field work sessions on the metmast, flight paths of individual birds or bird groups were followed as much as possible. Emphasis was laid on flight paths of birds flying through the wind farm, and less on birds flying outside the wind farm. Birds or bird groups were either picked up in the field with binoculars or telescope, or on the radar. Birds that were picked up on the radar were then looked up and identified in the field with binoculars or telescope.

These data yield information on flight behaviour of the birds in response to the wind farm, such as changes in direction, altitude or behaviour.

2.3.4 Nocturnal observations: auditory call registration

During nocturnal stays on the metmast, species information can be gathered on birds passing the wind farm area at night. This is of particular interest during the migratory period, when large numbers of non-marine migratory birds may pass the area. In this period, species composition at night is very different from that during daytime, because species have a strict preference for migration by night or by day. Species that can be observed during daytime, will not be present by night, and *vice versa.*

During hours of darkness, species identification can be achieved by call identification. In addition, species identification as well as visual registration of flight paths can be performed with moon watching (Lowery & Newman 1966, Schweizerische Vogelwarte 1996, see also Krijgsveld *et al.* 2005).

Although not all species call during migration at night, and although some species will therefore be missed, the nocturnal observations do give insight in species composition that would otherwise be absent, and as such are a powerful method to interpret flight patterns in the wind farm area.

During the reported study period, nocturnal observations could be carried out on one night (October 2-3 2007). On this particular night, the moon was too far away from being full to permit moon watching, and in addition was visible for only a brief period of time. Bird calls were registered ca. 10 minutes every hour. These data will be presented in the final report (2009).

In addition, a system has been developed by Leiden University in cooperation with Bureau Waardenburg, with which calls can be recorded automatically. This system is being installed on the metmast during the migratory seasons. It allows continuous recording of bird calls. Results will be part of the final report.

2.4 Radar observation methods

To obtain information on flight patterns on a larger scale, for an extended period of time, and on diurnal as well as nocturnal flight movements, radar was the best available option. The choice for radar, and more specifically, marine surveillance radar, for bird flight observations has been motivated in the strategy of approach for the baseline study (Krijgsveld *et al.* 2003).

The data recorded by radar provided the principle dataset on flight patterns, which is far more extensive than the visual observations due to the continuous nature of the measurements, the larger range, and the ability to record flight movements at night. In most weather conditions the radar has a superior detection covering larger distances compared to field observers, especially in the vertical plane.

2.4.1 Horizontal and vertical radar in general

Two types of radar observations were combined, horizontal and vertical.

- The first is the observation of **flight paths**, which was done using a **horizontal** marine surveillance radar (S-band). This is a standard radar as used on ships, that scans the area in the horizontal plane around the radar (fig 2.6, left panel). Using a radar in the somewhat longer S-band frequencies makes it easier for the radar to deal with sea clutter. With this radar, flight paths of birds flying through the radar beam were tracked and flight speeds and directions were recorded, as well as other flight characteristics.

- The second type of radar observation is the observation of **fluxes and flight altitudes**. This was done using a comparable type of radar (X-band), which was tilted to rotate **vertically**, and thus scanned the air vertically rather than horizontally (fig. 2.6 right panel). Using a radar in the relatively short X-band frequencies allows high-resolution target identification and information. In this way, bird flux could be quantified by counting the number of birds that crossed the radar beam during a fixed amount of time, and flight altitude of birds could be measured by recording the vertical distance of the bird to the sea surface.
- Technical specifications of both radars are given in table 2.5.

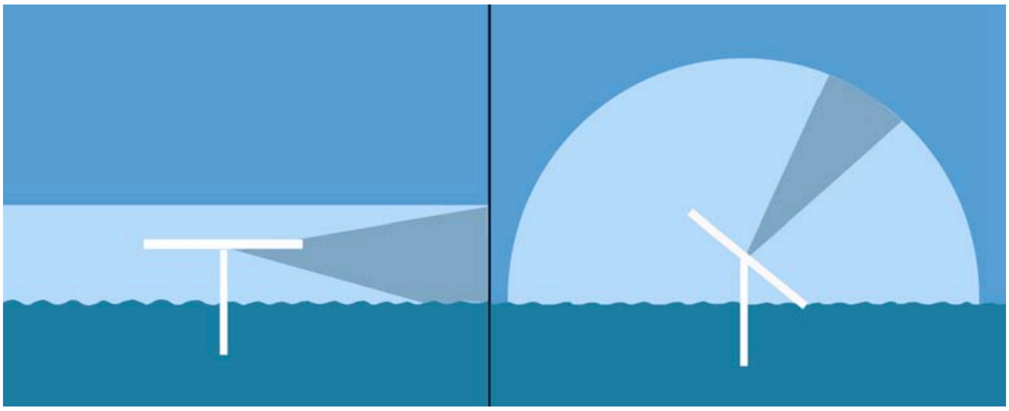

Figure 2.6 Schematic view of the horizontal (left) and vertical radar. Radar bundle is shaded in the image.

Table 2.5 Specifications of the vertical and horizontal radar.

	vertical radar	horizontal radar
wavelength freq	X-band	S-band
power	25 KW	30 KW
antenna length	2,50 m	3,00 m
beam width	20°	25°
rotation speed, avg	25 rpm	22 rpm
range	0.75 NM, *i.e.* 1389 m	3 NM, *i.e.* 5556 m
orientation	NW – SE	horizontal
altitude	axis at c. 13m	axis at c. 13 m above mean sea level
Merlin software	version 3.4.44	version 3.4.44

The radars scanned an area of up to 6 km (3 NM) around and up to 1,5 km (0.75 NM) above the observation platform. They automatically recorded echoes continuously throughout the year, every day, both day and night, and thus recorded all bird movements within the area. In this way, the exact location, direction, speed, and altitude was registered of all birds flying within the scanned area.

Horizontal and vertical radars as positioned on the metmast in the OWEZ wind farm area. Photo: M. Poot.

2.4.2 Merlin system

To process and record echoes detected by the radars, Merlin, a system developed and supplied by DeTect Inc. (Panama City, FL, USA), is being used. This system entails not only the radars, but also computer-radar interfaces and software. With this system the radar signal can be processed and recorded, yielding a database in which echoes belonging to birds are stored along with information on flight direction, speed, altitude and more.

Recording echoes

In brief, the Merlin system functions as follows. An object (a bird or group of birds, but also ships, clutter) is detected by the Furuno radar (the 'black box' in fig. 2.7). Subsequently the signal is digitised in PC 1 (signal processor; located at the metmast) and sent to PC 2 (data storage; located in the onshore substation in Wijk aan Zee). Here it is processed with specialised Merlin software in order to identify signals as belonging to birds or not, and simultaneously to get rid of as many false echoes (clutter) as possible. Subsequently, all tracks classified as birds are stored in a database in PC 2. Subsequent echoes identified as belonging to a single object (the echo track or trail) are given similar id's in the database. This enables analysis of the flight path of that object.

Radar echoes can thus be seen on screen in two ways; both as an unprocessed image from the Furuno radar, visible on the '**Furuno screen**' and as an image processed by the Merlin software, visible on the '**Merlin screen**' (fig. 2.8). This differentiation is of importance in the calibration experiments (chapter 3).

Echo characteristics

The Merlin system records a large number of characteristics of each signal that is detected. These characteristics can be used to separate between actual birds and erroneously recorded objects other than birds (clutter). Echo characteristics include, among others, speed (relative to ground surface), size (relative to distance), signal strength and reflectivity (for further information see (Krijgsveld *et al.* 2005)). Echo characteristics that were stored by the Merlin system are listed in table 2.6.

Data analysis

Data are processed and analysed using the statistical software packages SPSS version 15, and R. In addition, GIS is used to visualise patterns. For purpose of analysis of flight patterns, the radar data were reduced and summarised to 1 record per track.

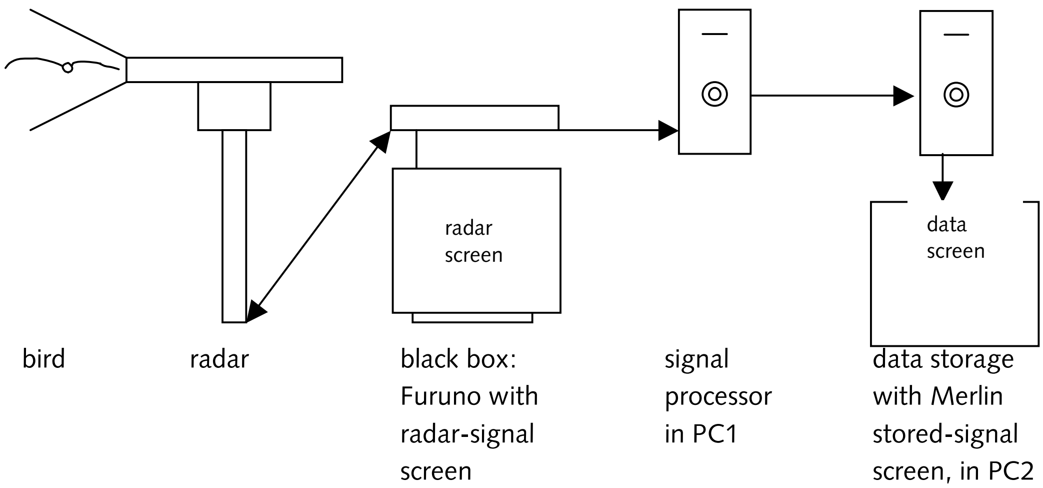

Figure 2.7 Schematic overview of the horizontal radar equipment used. The setup for the vertical radar is identical.

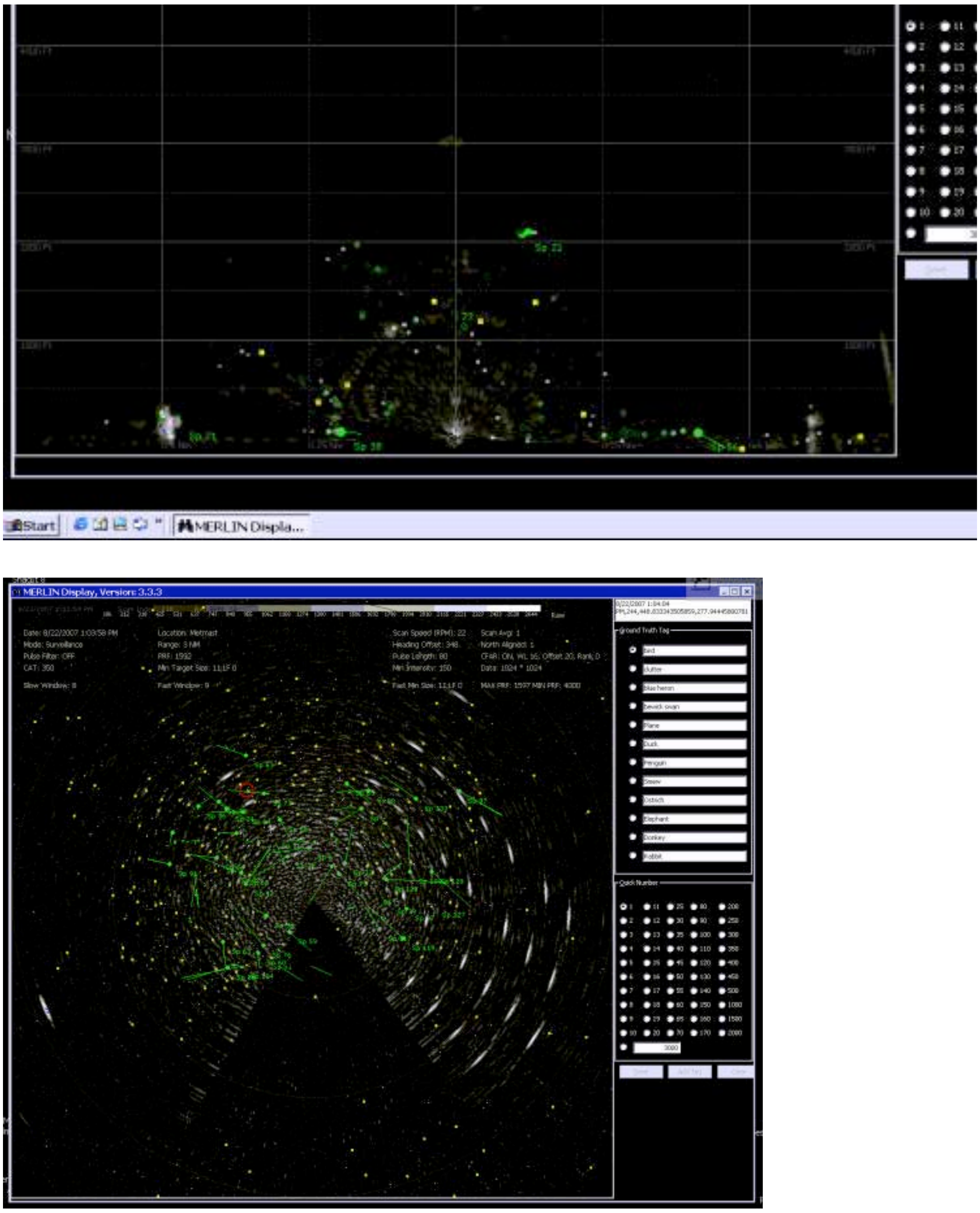

Figure 2.8 Image of the Merlin screens of the vertical (top) and the horizontal (bottom) radars. Green dots reflect recorded tracks with flight direction indicated by a green line; yellow dots potential bird tracks; white non-recorded signals received by the radar. Visible on the vertical screen are two turbines as well as interference around the radar (white), and three bird tracks. Visible on the horizontal screen are the various turbines, clutter (white) and numerous tracks of mainly sea clutter on a windy day (green).

Table 2.6 List of echo characteristics registered and logged by the Merlin system of DeTect Inc. for both the horizontal S-band and the vertical X-band radar.

S-band Data	X-band Data	Definitions
DBASE ID	DBASE ID	Unique database identification number for each echo identified in the radar data. These are supposed to be birds, but may also be boats, airplanes, waves, or other clutter.
Period	Period	Link to Session Metadata with this field. This is a Unique ID for the Session
Date	Date	Date and Time - dd/mm/yyyy etc.
Scan Index	Scan Index	How many seconds into the current hour the scan is made (max 3600)
Target Index	Target Index	The number assigned to the target in the current scan, targets in the same scan are numbered from top left to bottom right of the display
Area	Area	Area of the target in pixels
Max Segment	Max Segment	Longest length across the target
Perimeter	Perimeter	Perimeter of the target measured in pixels
Orientation	Orientation	The angle of the longest axis of a target with respect to the horizontal axis. This value is between 0 - 180 degrees.
Ellipse Major	Ellipse Major	Length of the major axis of an ellipse that has the same area and perimeter as the target
Ellipse Minor	Ellipse Minor	Length of the minor axis of an ellipse that has the same area and perimeter as the target
Ellipse Ratio	Ellipse Ratio	Ratio of Ellipse Major to Ellipse Minor
Elongation	Elongation	A measure of the elongation of a target, the higher the value the more elongated the target
Compactness	Compactness	Ratio of the target's area to the area of the smallest rectangle that contains the target
Heywood	Heywood	Ratio of the perimeter of the target to a circle with the same area as the target
Hydro Radius	Hydro Radius	Ratio of target area to it's perimeter
Waddel Disk	Waddel Disk	Diameter of a circle with the same area as the target
Mean Intercept	Mean Intercept	The mean length of segments along the length of a target
Max Intercept	Max Intercept	The length of the longest segment of an echo, in any direction
Type Factor	Type Factor	
Mean Chord X	Mean Chord X	The mean length, in pixels, of the horizontal segments of a target
Mean Chord Y	Mean Chord Y	The mean length, in pixels, of the vertical segments of a target
Av Reflectivity	Av Reflectivity	Average reflectivity over the entire target area (Max 4096)
Max Reflectivity	Max Reflectivity	Maximum reflectivity over the entire target area (Max 4096)
Min Reflectivity	Min Reflectivity	Minimum reflectivity over the entire target area (Max 4096)
Std Dev Reflectivity	StdDev Reflectivity	Standard deviation in reflectivity over the entire target area (Max 4096)
Range Reflectivity	Range Reflectivity	Range in reflectivity over the entire target area (Max 4096)
Range	Range	Distance from the radar to the target in a direct line
Bearing	Bearing	Bearing from the radar to the target
Distance FT		Distance in feet away from the S-band radar location
Track ID	Track ID	Unique identifying number for each track. At least 3 echoes are required to make a track. If a track is broken for two or more scans but then reappears, then a new track is started
Track Type	Track Type	
Target X1	Target X1	X coordinate in pixels of the centre of the current target in a track
Target Y1	Target Y1	Y coordinate in pixels of the centre of the current target in a track
Target X2	Target X2	X coordinate in pixels of the centre of the target from the previous scan in this track
Target Y2	Target Y2	Y coordinate in pixels of the centre of the target from the previous scan in this track
Target X3	Target X3	X coordinate in pixels of the centre of the target from the 3rd oldest scan in this track
Target Y3	Target Y3	Y coordinate in pixels of the centre of the target from the 3rd oldest scan in this track

Table 2.6 Continued.

S-band Data	X-band Data	Definitions
Target X4	Target X4	X coordinate in pixels of the centre of the target from the 4th oldest scan in this track
Target Y4	Target Y4	Y coordinate in pixels of the centre of the target from the 3rd oldest scan in this track
Lat 1		Latitude of the centre of the current target in a track
Long 1		Longitude of the centre of the current target in a track
Lat 2		Latitude of the centre of the target from the previous scan in this track
Long 2		Longitude of the centre of the target from the previous scan in this track
Lat 3		Latitude of the centre of the target from the 3rd oldest scan in this track
Long 3		Longitude of the centre of the target from the 3rd oldest scan in this track
Lat 4		Latitude of the centre of the target from the 4th oldest scan in this track
Long 4		Longitude of the centre of the target from the 4th oldest scan in this track
Heading	Heading	Azimuth heading of a tracked target (0 - 359 degrees)
Speed	Speed	Speed of a tracked target in the units specified in the Metadata Table of the database
Class	Class	
	AGL FT	Altitude Above Ground Level of a target – this is altitude above the X-band radar, which itself is 20 m above the water
	Cross Track Ft	Distance in feet along the surface of the water or ground that a target is away from the radar

2.4.3 Data collection with vertical radar

Data collected with the vertical radar concern fluxes and flight altitudes of birds. The data that were analysed and that are discussed in the report at hand, cover the period between the 19th of March 2007 and the 27th of October 2007. In the reported period the vertical radar was not operated all the time (3085 out of 5304 hours; 58%) due to weather conditions and maintenance. The second half of the season the radar operated on a more regular basis than during the first months of the project, and was only shut down during periods with strong winds (> 7 Bft). Time from the 3rd of July until the 27th of October that the vertical radar was operational was 2340 out of 2784 hours, or 85% of the time.

Not all tracks recorded by Merlin were tracks of birds or bird groups, but were erroneously recorded tracks originating from clutter such as the movement of the turbine rotors or interference from other radars. To be able to remove these data from the database, a series of tests and experiments were done to identify and discriminate between records from birds and clutter. This is described in chapter 3.

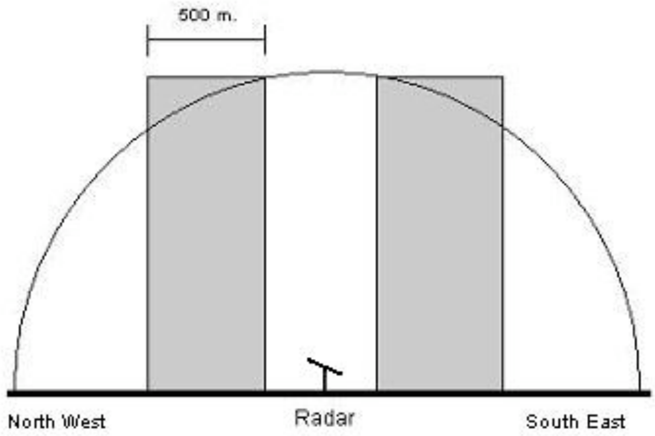

Figure 2.9 Schematic view of the two columns (grey area) in which all tracks were selected for analysis of flux and flight altitude. Columns are each 500m wide.

2.4.4 Data collection with horizontal radar

Data collected with the horizontal radar concern flight paths of birds. The data that were analysed and are discussed in the report at hand, cover the period between the 3rd of April 2007 and the 22nd of October 2007. From April through to the end of October, Merlin detection settings have remained more or less similar, after testing of the settings through most of February and March. In this reported period, the radar has been operational almost continuously (offline end of May – mid June).

Data analysis horizontal radar
To allow analysis of the data on flight paths of birds, data recorded were reduced to 1 record per bird group (*i.e.* per trackID). For each record, general information concerning the entire track or flight path was stored as well, such as length of the track, flight direction and speed, original and final position in the wind farm area, signal quality of the track.

Echoes from waves (sea clutter; resulting from radar energy reflected by waves) were erroneously stored in large amounts in the database, as described in chapter 3 (see also results from the baseline study in Krijgsveld *et al.* 2005). This is a problem when using (any type of) radar at sea. At this moment, techniques have not been established to effectively remove the clutter from the database, although we are able to statistically reduce the amount of clutter in the database substantially. Similar to the vertical radar, a series of tests and experiments was done to assess the proportion of clutter in the database and to separate between records from birds and clutter. This is described in detail in chapter 3.

Because clutter currently cannot be removed sufficiently from the horizontal radar data, a strong selection was made of data that were fit for analysis. These included only days with calm weather, on which waves were so calm that sea clutter was more or less absent from the data base. In addition, days were selected on which visual observations were carried out as well, to allow critical interpretation of the results obtained.

Depicting data from horizontal radar

To depict flight directions and flight intensities in the wind farm area, a virtual grid was placed over the wind farm area consisting of cells of 1x1 km, following (Petersen *et al.* 2006). Within each of these cells, the average flight direction was calculated, as well as the total number of tracks recorded. For the report at hand, a strong selection of data was made, showing only a limited number of days per season. This was done because sea clutter contaminated the majority of the data too much to be able to reliably extract flight patterns of birds (see chapter 3).

2.4.5 Visual monitoring of radar

Some standardised observation methods were used to allow evaluation and calibration of both the vertical and the horizontal radar, as well as to provide an alternative data base on flight patterns. These methods are described below.

Visual counts of bird tracks on vertical radar

Bird tracks visible on the vertical Furuno screen were recorded during field work sessions on the metmast. Data were recorded in 5-minute time intervals, and were classified in 10 altitude bands of approximately 140 m each (=0,75NM/10). Furthermore, tracks were recorded in either of five vertical columns (2 of which correspond to the columns analysed in the Merlin data), and flight direction was recorded as well (to the left, to the right, or perpendicular). This provides a measure of the accuracy with which Merlin records bird tracks, because it allows comparison of flux as recorded by Merlin (and presented in this report), and flux as observed visually on the raw radar screen.

Similarly, bird tracks visible on the vertical Merlin screen were recorded regularly in the same way. This could be done at any time, by remotely logging in on the Merlin computer. This dataset allows an additional analysis of the effectiveness of the clutter filter, as visual monitoring results in a database of actual bird tracks with clutter excluded.

Visual counts of bird tracks on the horizontal radar

To estimate the number of tracks within versus outside the wind farm, as well as to be able to compare the tracks seen by the radar (on the Furuno screen) with those recorded by Merlin, we made digital movies from the Furuno screen. Tracks in these films were counted visually in two 90° fields of each time frame. One field was positioned outside the wind farm, the other inside the wind farm (fig. 2.10).

Data were recorded on seven days throughout the study period, from three to seven videos taken throughout the day. From each movie, one single time frame was counted, thus providing data in a spot sample fashion (*i.e*. one radar scan).

By linking these data to the data recorded by Merlin at that time, they could be used to validate and calibrate the Merlin data.

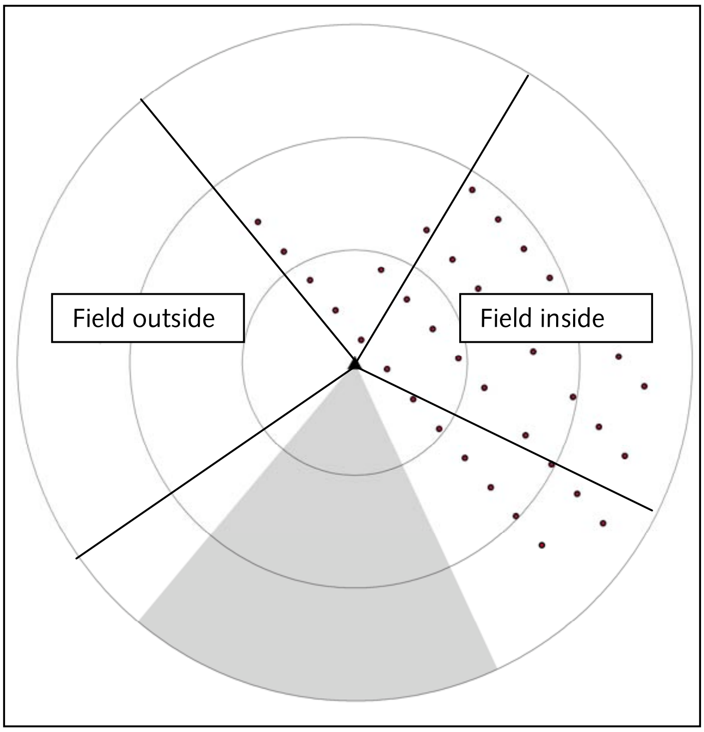

Figure 2.10 Schematic view of the two fields in which flight movements were counted.

3 Data calibration

In this chapter we present data that were collected in order to monitor, calibrate and evaluate the performance of the vertical and horizontal radar systems.

Radar data are being collected 24/7 through an automated detection system (Merlin). This system is one of the best systems currently available to record data at sea (where access for researchers is very much limited) and to record data at night (when visual observations are not possible). However, not all birds seen on the Furuno radar screen are detected, and objects other than birds can be detected and recorded as birds in the database (clutter). Detection and recording of data was further improved compared to the baseline study, based on reduced range (1,5 to 0.75 NM for vertical radar, 6 to 3 NM for horizontal radar), as well as improvements made by DeTect in new versions of the Merlin software.

A series of tests has been carried out in the study period reported here, to analyse the performance of the two systems. The results of these tests are briefly discussed below. The calibration data will be extended in the coming year of study. The complete outcome of the various detection experiments will be described in the final report of this research programme.

3.1 Vertical radar

3.1.1 Detection experiments

Comparison of tracks recorded by Merlin and seen on Furuno screen
The most direct test of the performance of the Merlin system in detecting birds which is possible within this project, is a comparison of the numbers of tracks visible on the Furuno screen (raw radar) and the numbers of tracks recorded by Merlin in the same time span.

Simultaneous recording of flight movements observed on the Merlin screen (in the BuWa office) and on the Furuno screen during fieldwork, gives detection chances of Merlin compared to visual detection from 'raw' radar. Two observers were connected by telephone and recorded and discussed all bird tracks present on both screens. As shown in table 3.1, 179 tracks were recorded, of which 79% was correctly detected. The remaining 21% of incorrect detections can be divided in 9% where a bird was seen on the Furuno screen but not recorded by Merlin (detection failure), and 12% where a track that was recorded by Merlin but not seen on the Furuno screen. The latter error may occur either when a bird flies in an area with heavy clutter on the Furuno screen and is thus invisible to the eye, or when a non-bird is logged erroneously by Merlin as a bird in the database. If the latter is the case, this track should be filtered out during the database treatments described in the following parts of this paragraph.

Table 3.1 Results of detection experiment by simultaneous recording of flight movements on Furuno and Merlin screen. 79 % of the tracks was correctly detected by Merlin and saved in the database.

	Number	Chance (%)
Total number of sightings	179	
Chance of correct detection	141	78,8
Chance Furuno positive and Merlin no sighting	16	8,9
Chance Furuno no sighting and Merlin positive	22	12,3

In addition to the comparison described above, a more extensive comparison can be done by relating all visual counts from the Furuno screen to the data recorded simultaneously by Merlin. This results in a larger database and hence a more reliable estimate of the percentage of errors. For this purpose, Furuno recordings during fieldwork can be linked to the Merlin data that were recorded simultaneously. This analysis will be presented in the final report.

Detection probabilities in relation to heading

Birds flying head-on into the radar beam, somewhat toward the radar itself, have a higher chance of being detected by the radar than birds that approach the radar in such a way that the beam hits the tail side of the bird (flying somewhat away from the beam). Due to these different detection probabilities in relation to heading of the bird, overall differences in detection probability may occur between the south-eastern and north-western side of the radar beam. This was the case in the baseline study, where birds flying NE on spring migration had a higher detection probability in the southern than in the northern side of the radar beam (Krijgsveld *et al*. 2005). However, in contrast to the baseline study where the vertical radar was oriented N-S, the radar is oriented SE-NW in the effect study on the metmast. This is largely due to the layout of the metmast. As a consequence, the radar is currently positioned almost perpendicular to the main flight direction during spring migration, and detection thus is expected to be more or less similar for migrating birds that fly in NE/SW directions.

To test whether heading effects still occur in the current database (despite the perpendicular orientation), mean traffic rates (MTRs) were calculated for data from the north-western and the south-eastern sides of the radar separately. MTR was consistently lower in the north-western part of the radar beam, during all months (fig. 3.1). Compared to the baseline study, the difference between the south-east and north-west side was much smaller, possibly as a result of the more perpendicular angle of the radar to the main flight direction. If the difference that is visible is related to heading aspects, one would expect the ratio to change in relation to season: in spring a pattern opposite to that in autumn should emerge. Additionally, during the summer months, when locally foraging birds dominate the flight paths, no consistent difference between both sides of the beam would be expected.

It is currently unclear what causes the consistently lower MTR in the north-western part of the radar. Possibly, gull movements, which dominate the visually recorded flight paths, affect this pattern. Diurnal patterns in flight directions of gulls could however not shed light yet on this problem. In spring, mean flight directions of gulls were oriented NW at dawn, and also NW to W at dusk. Numbers were higher at dawn than at dusk though (which would result in higher detection probability in SE side of beam, conform findings). In summer, flight movements were oriented mostly SE at both dawn and dusk, and with similar numbers (should result in higher detection probability in NW side of beam, contrary to findings). In autumn, movements were oriented E at dawn and, with higher numbers, N to NW at dusk (resulting in higher detection probability in SE side of beam, conform findings).

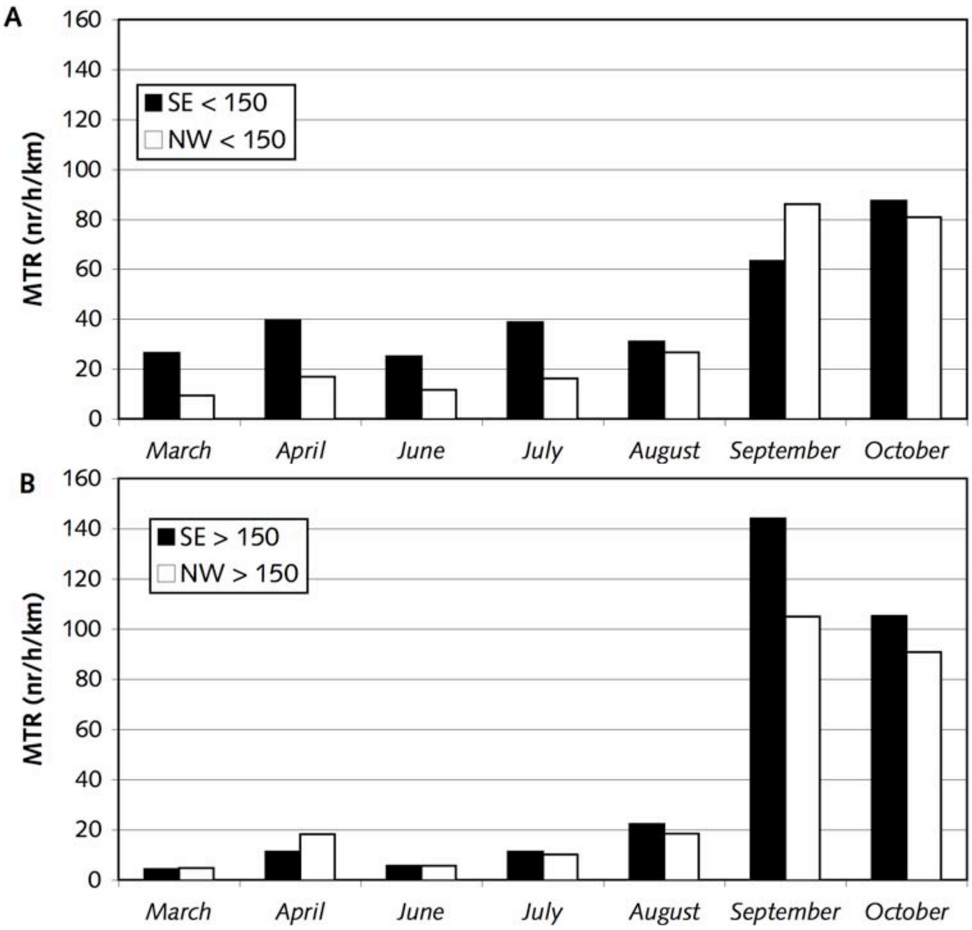

Figure 3.1 Differences in Mean Traffic Rate between the south-eastern (black bars) and the north-western part of the radar screen (white bars). Data from altitudes below 150 m (A) and above 150 m (B), for day and night combined, as measured by vertical radar. Note that the north-western part of radar screen consistently shows lower numbers.

3.1.2 Data filtering

The Merlin software is designed to only select and record tracks originating from birds, based on echo characteristics such as speed, size and intensity that are characteristic for birds. When objects other than birds (interference from other radars and from the metmast, and wind turbines, weather, insects, ships) produce an echo with characteristics similar to those of birds, these echoes can be erroneously stored in the database. Compared to the baseline study (Krijgsveld *et al.* 2005) the amount of clutter recorded on the vertical radar has decreased substantially, due to new techniques and updated versions of Merlin. However, as shown in the above paragraph, clutter still is recorded to some extent. It is important to be able to distinguish these echoes from those of actual birds, to clean up the database and obtain a clear picture of bird movements at the wind farm area. The process of data filtering is described in this paragraph.

To determine the characteristics of various bird and non-bird radar echoes, a 'flagfile' was built; a dataset of echoes recorded by Merlin, that have been identified as bird or clutter (*i.e.*, interference, ship, turbine, etc.). This identification was achieved through visual observation of the Merlin screen. Tracks on the Merlin screen differ clearly between those of birds and non-bird objects. Interference generates 'tracks' in random directions, without an apparent track. Wind turbines are visible on the screen, and 'tracks' generated by the rotor are visible as such at the location of the turbine. Birds create consistent, regular tracks. A flag was only assigned to a record when identification was positive.

A total number of 1063 flags have been assigned during the reported period, on 23 different days (table 3.2).

Table 3.2 Number of flagged echoes for vertical Merlin data.

group	nr of flagged tracks
clutter	488
bird	432
turbine	59
weather	71
insect	11
ship	2

To be able to distinguish between different groups (bird and non-bird) in the data, the characteristics of echoes recorded by Merlin need to vary between groups (most importantly birds versus non-birds). Preferably, the groups do not overlap at all, since this would make it easy to classify the echoes. However, in practice characteristics do overlap, making it more difficult to assess whether a certain value of a characteristic represents a bird or clutter. Differences between the various groups were analysed by making boxplots of the echo characteristics, to give an indication of the variability within and between the different groups. Reading a boundary value from the graph between two groups gives an indication what criteria can be set for the different echo characteristics.

There were several echo characteristics of flagged echoes that differed markedly between birds and the various types of clutter. However, none of the characteristics showed a clean difference without overlap, nor did any combination of echo characteristics. Based on the observed differences, 'threshold values' of various characteristics were determined to be able to remove clutter from the vertical radar database. These thresholds were set to such a level that no bird records would be removed, because clutter formed a minor proportion of the data in general, and removing a fraction of the bird records would have large effects on the entire database. Echo characteristics that showed the largest difference between groups and that were used to differentiate between birds and non-birds were (fig. 3.2):

- range
- altitude
- track quality
- sd of heading
- track length
- ellipse minor
- type factor

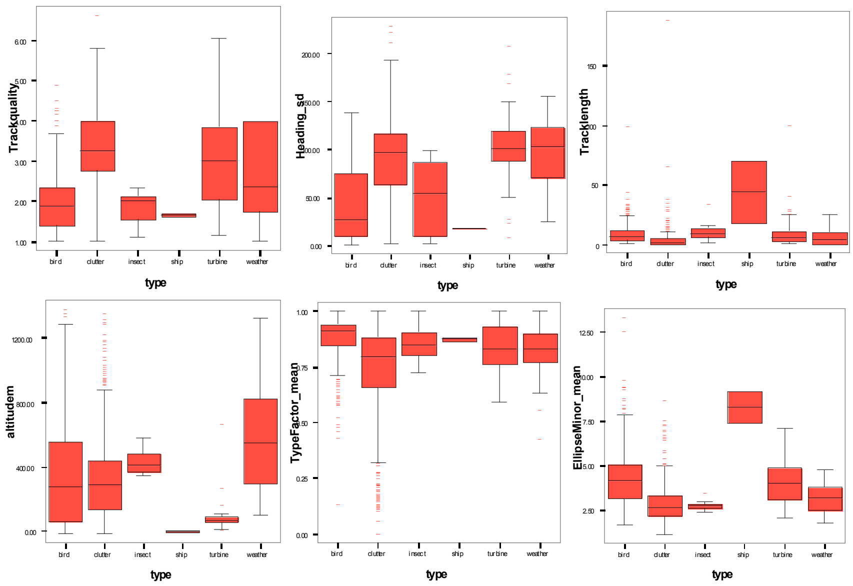

Figure 3.1 Boxplots of flagged echo characteristics of vertical Merlin data, used to assign criteria (boundary values) for the distinction between different groups of objects. Shown are track quality, heading sd, track length, altitude, ellipse minor mean and type factor mean. Box: 50% of data, horizontal line: mean.

Track quality is defined as summed track type divided by total track length (*i.e.* long tracks that were consistently detected by Merlin), and is a measure of the quality of the track. This proved to be a distinctive measure for bird compared to non-bird tracks. The same holds for ellipse minor (length of the minor axis of an ellipse that has the same area and perimeter as the target object) and type factor (another measure for track quality). Also the heading turned out to be important to distinguish between bird and non-bird tracks, as the standard deviation of the heading of the birds was smaller than in irregular non-bird tracks. In table 3.3 all thresholds for the determining factors are given.

Table 3.3 Criteria and threshold values for discriminating echo characteristics to remove non-bird tracks from the Merlin database. '% reduction' indicates the effect of the main filtering rules on reduction of the database, i.e. the reduction in records in the database after the criterium has been applied. The % removed with the second rule (altitude) is irrelevant as the step was carried out in combination with the step to assign one record per track and therefore reflects a compression of data rather than a filtering out of clutter.

echo characteristic	criterium and threshold level	% reduction
range	tracks at a range < 206 m or > 0,75 NM were removed	29
altitude (m)	tracks with an altitude < -1,5 m were removed	-
tracklength	tracks with a tracklength < 3 hits were removed	70
trackquality	tracks with a trackquality > 4,89 were removed	0
heading sd	tracks where st. dev. of the heading was > 138 were removed	13
ellipse minor	tracks with an ellipse minor < 1,795 were removed	16
type factor	tracks with a type factor < 0,46 were removed	11

Applying the above criteria, bird and clutter objects in the flagged database were marked as either clutter or bird. The accuracy of the criteria could then be evaluated by comparing the classification to the manual classification. Results were:

- 99.3% of records manually identified as bird, fell within bird-criteria (Correct)
- 0.7% of records manually identified as bird, fell outside bird-criteria (Wrong*)
- 51.3% of records manually identified as non-bird, fell outside bird-criteria (Correct)
- 48.7% of records manually identified as non-bird, fell within bird-criteria (Wrong**)

* records were erroneously classified as clutter and removed from the dataset.

** records were erroneously classified as bird and stayed in the dataset.

Although these criteria did not remove all clutter (49% of flagged data) and removed a small percentage of bird-echoes as well (1% of flagged data), this was the best possible way *currently* available to remove clutter from the database. The first group (49%) incorrectly remains in the flagfile. This is an important feature as these data pollute the database with tracks that are not from birds but can't be filtered out with the applied criteria. Although these data reach 50% of all data in the flagfile, the percentage will be lower in the actual database, because they can be filtered out to a large extent based on e.g. position (turbines). Percentage of data removed as clutter in the various steps of clutter removal from the Merlin database is shown in table 3.3 as well. Currently it is unclear what the exact percentage of clutter in the vertical database is, but the results obtained thus far show that the database is rather clean and does reflect flight patterns of birds well.

Analysis of data on visual Furuno counts versus Merlin data (§2.3.3) will give an indication of the amount of clutter saved in the actual database in the first place. This will improve the general information on clutter pollution of the database.

To reduce the amount of clutter present in the database, several other database treatments have been done. Obviously all tracks with a range (distance radar – target) beyond 0,75 NM were removed from the database as they are situated outside the limit to which detection range of the vertical radar was set. The backlobe of the radar beam, turbines T7 and T8 that are closest by, as well as interference from the metmast produced large amounts of clutter up to 206 m from the radar (increased frequency of non-bird tracks). Consequently, all data within 206 m from the radar were removed from the data. All records at or below sea level outside the tidal range reflect sea clutter and were removed from the data set (altitude < -1.5 m). The wind turbines generated quite a lot of tracks in the database due to movement of the rotor blades. Removing all tracks generated on positions where turbines were placed reduced the overall amount of data in the analysed databases by 25%.

Clutter from interference

Clutter from interference (e.g. the safety radars operational in the wind farm, that were turned on after the majority of the X-band detection tests were done) currently creates a substantial amount of clutter in the database. This clutter may prove difficult to remove, as it is present in areas of the beam that are used for data analysis. Analysis of recent data and further calibrations in the following months will shed light on the current status of clutter in the database as well as effectiveness of clutter removal.

3.2 Horizontal radar

3.2.1 Data calibration experiments

Correlation between wave height and amount of data recorded

The received echo signal from Merlin is processed by a threshold logic. This threshold is balanced in such a way that a certain amplitude or intensity of wanted signals (of birds) are able to pass and also noise will be removed. At sea, any kind of radar will detect waves very well. In sea clutter there exist high noise tops (waves, seen very well by any radar) which lie in the range of the small signals that we want (birds). Because of this, the optimized threshold level in Merlin for recording is always a compromise between avoiding clutter and recording bird tracks. To investigate whether sea clutter was recorded in the database, and to what extent, we analysed the correlation between the amount of data recorded and the weather conditions, such as wave height.

Data recorded on the horizontal radar system are written to files, that are stored as soon as the file size has reached a certain size, after which a new data file is created. Thus, the number of files written on a specific day gives an impression on the amount of data recorded. Figure 3.2 shows the relationship between weather and the number of files (*i.e.* tracks) recorded. The number of files increased significantly with wave height and wind speed. This means that on windy days and/or days with higher waves, the amount of sea clutter in the database is substantially higher.

This means that the highest percentage of tracks of birds will be found in data from days with the calmest weather conditions.

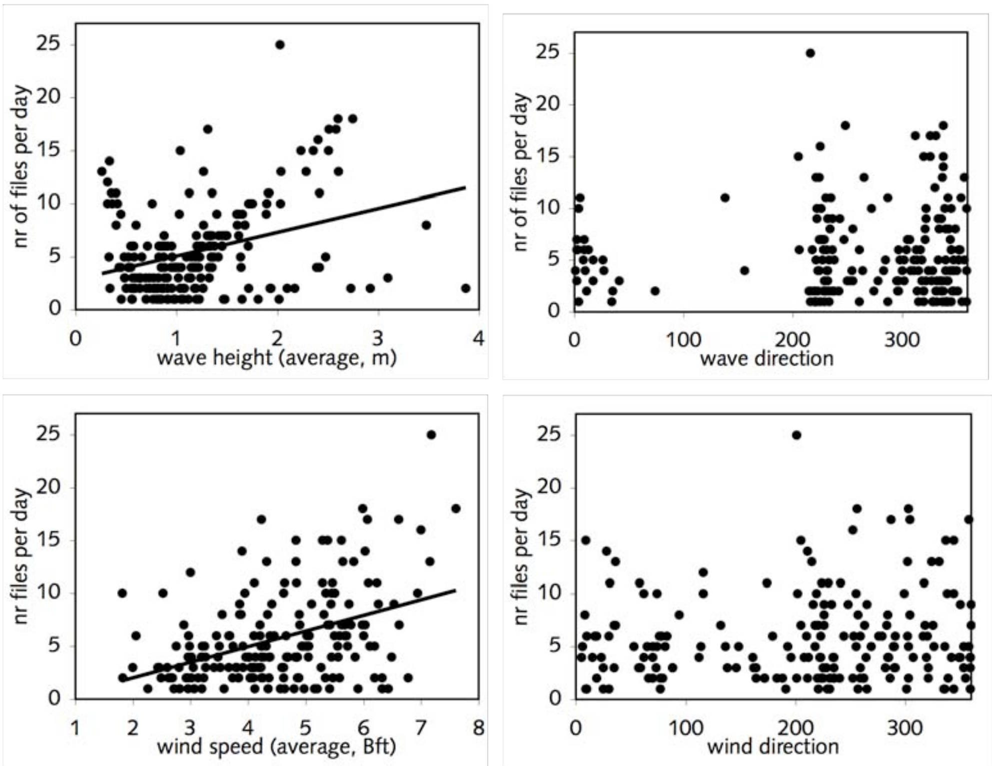

Figure 3.2 Relation between number of tracks recorded, visualised as nr of files stored per day, and weather conditions. Directions are calculated as mode per day.

3.2.2 Data filtering

Flagging

Clutter can ideally be removed from the database, if echo characteristics of birds differ from those of other objects such as sea clutter. To be able to analyse differences in echo characteristics, the tracks recorded in Merlin need to be identified visually. Similar to the vertical radar, a database was built in which echo characteristics were stored of tracks that were recorded in Merlin and that were known to originate from birds, ships, or sea clutter (see §3.2.1 for a more detailed explanation of this process, as well as Krijgsveld *et al.* 2005).

This 'flagging database' (table 3.4) currently is not large enough to allow a reliable analysis of echo characteristics. The main reason for this is that often it is not positively clear whether a track is of clutter or a bird. This difference is much more obvious for the vertical data, for which the database is considerably larger. The database will be expanded in the remainder of the study period, and results of the analysis will be presented in the final report.

Table 3.4 Number of flagged echoes for horizontal Merlin data.

group	nr of flagged tracks
bird	225
clutter	95
ship	6

Data selection

The large amount of sea clutter in the data together with the absence of a calibrated clutter filter at the time of reporting, means that for the report at hand the data need to be selected in a different way to avoid presenting patterns of clutter. For this purpose, only data from calm days with little sea clutter were chosen. In addition, data were chosen from days on which visual observations were carried out. This allows us to evaluate the flight paths given by Merlin. Furthermore, only those objects were selected that were seen for a longer period of time, and thus had longer tracks (track lengths of more than 10 scans). Longer tracks have a higher chance of originating from birds.

4 Results on fluxes

In this chapter data are presented on the flux, or the flight intensity, of birds flying in the area of the OWEZ wind farm. First, overall patterns in flux are shown, based on the data collected with the vertical radar. These give a picture of flux of all birds in the area combined, at different times of day and night as well as throughout the season (§4.1). Second, patterns are shown for individual species or species groups, based on the visual observations (§4.2).

Flux is calculated as the Mean Traffic rate (MTR), *i.e.* number of birds passing an imaginary line of 1 km long in one hour. The occurrence of different bird species (both species composition and numbers) varies year round and inter-annually in the Dutch coastal waters. These changes are linked to the annual cycle of species, due to which local breeding birds are expected in summer, migrants mainly in autumn, and spring and winter visitors in winter. In addition, environmental conditions affect the occurrence of birds above sea.

Bird migration takes place over a wide range of altitudes. At some altitudes birds experience a higher risk of collision with wind turbines than at others. Flight activity at the various altitudes is reported in chapter 6.

4.1 General patterns (from radar observations)

Fluxes throughout the year, during day and night
Fluxes showed a clear difference between the various reported months (fig. 4.1). Figure 4.1 shows reasonably consistent fluxes throughout spring and summer, and a peak in September and October during autumn migration. Bird migration generally reaches higher fluxes during night than during day. At night, collision risks with wind turbines are expected to be higher due to reduced visibility. For this reason it is important to differentiate between day and night. Clear differences in MTR during day and night were visible in all months (fig. 4.2). Below, the results are described for each of the seasons.

During the period of **spring** migration, MTRs were only slightly elevated, much less distinct than in autumn. In April, the radar system was in the process of being installed and tested, and the number of days for which data are available is therefore limited. The dates on which data were recorded, did hardly have suitable weather for spring migration. The only dates in April on which data was collected were the 1st, 2nd, 12th until 16th. All these days, except for the 15th, had east, north-east or northerly winds up to 5 Bft, which is not suitable for the generally north-west directed bird migration in spring. On the 15th of April wind was south-east 3 Bft, which is not ideal for migration but not particularly bad either. As a result this low MTR reflects gaps in the database rather than a lack of migratory activity in the area. Similarly, MTR was higher during day than during night, which also is contrary to expectations. Data collected in the spring of 2008 will give a more representative image of flux in the area during spring.

In **summer**, fluxes were relatively low, reflecting mainly local flight movements of gulls (§5.2). Interestingly, flight activity at night still reached levels of ca. 10-20 bird groups/h/km. This probably reflects flight activity of gulls, that have been seen and heared at sea at night (visual observations current and baseline study).

The expected peak in bird numbers during the **autumn** migration period are birds coming from north-easterly directions (Scandinavia) flying south-west and west to the wintering grounds. Remarkably, MTR in September was higher during day than during night. The reason for this pattern is unclear at this moment, and cannot be explained by availability of the radar system. In October, MTR was higher at night than during day. MTRs probably largely reflect thrushes migrating through the wind farm area.

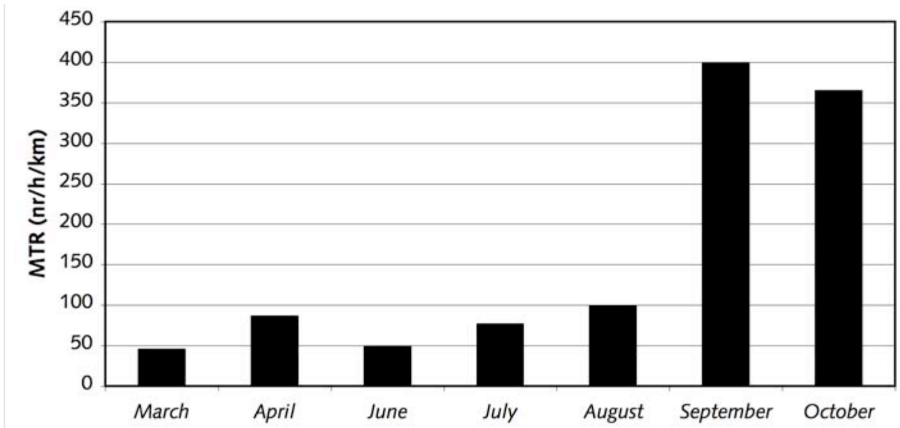

Figure 4.1 Mean Traffic Rate for all altitudes and both day and night combined, as measured by vertical radar. MTRs shown are averages for the entire month. Note the high MTRs in September and October during autumn migration.

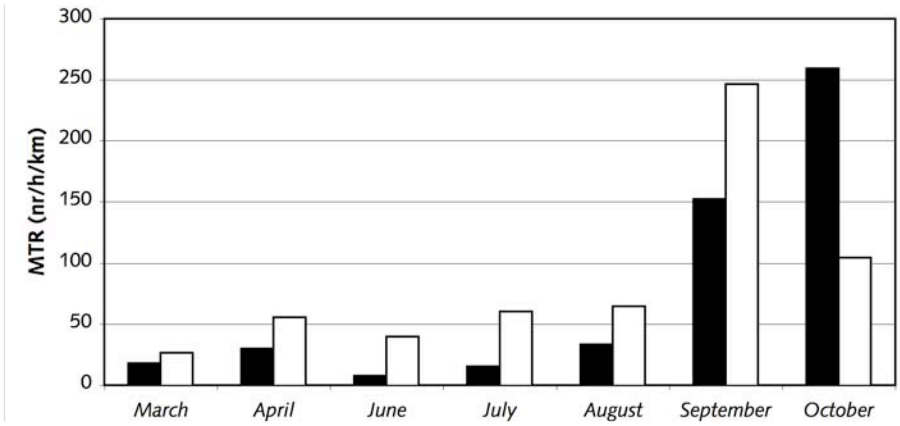

Figure 4.2 Mean Traffic Rate during day (white bars) and night (black bars). Data for all altitudes combined and averaged over the entire month, as measured by vertical radar. Note the high MTRs in autumn, during daytime in September and during nighttime in October.

Differences in MTR between days within the month

Not all nights of a specific month are equally busy with flying birds. Weather conditions and timing of the year are important factors that affect the MTR in a month. Table 4.1 shows the peak MTRs per hour in each month. The highest MTR was measured in the night from the 17th to the 18th of October, with 3410 bird groups/hr/km. This was a night in the middle of the migratory season, with north-westerly winds up to 6 Bft. In the entire night around 22.000 bird groups per km passed the OWEZ wind farm. Of these, around 11.000 groups flew at altitudes above 250 metres.

Table 4.1 Hours during which highest fluxes of flying birds were recorded over the wind farm area, calculated as MTR (nr/h/km) and given for each month.

Peak hour		# of birds
30-03-2007	05:00 - 06:00	86
03-04-2007	16:00 - 17:00	1515
20-06-2007	17:00 - 18:00	406
19-07-2007	18:00 - 19:00	949
22-08-2007	02:00 - 03:00	1505
17-09-2007	01:00 - 02:00	2240
18-10-2007	02:00 - 03:00	3410

Diurnal variation

Besides seasonal patterns, also flight activity during the day and night shows variation. For example, in late summer and autumn, high migration activity is expected to result in relatively high MTRs during the night compared to the day. In the breeding season, flight activity is expected to be limited mostly to daytime. Figure 4.3A-G shows the daily patterns in MTR in the various months. It clearly shows that migration occurred especially in the beginning of the night (October). The general pattern in the remaining months shows slightly increased flight movements during the day and less during the night. The peak in MTR around 16:00 h in April originates from one single date (3rd April 2007) and cannot be explained so far, although all tracks have an abnormally high velocity on this day. Final conclusions will be made in the final report to be published in 2009.

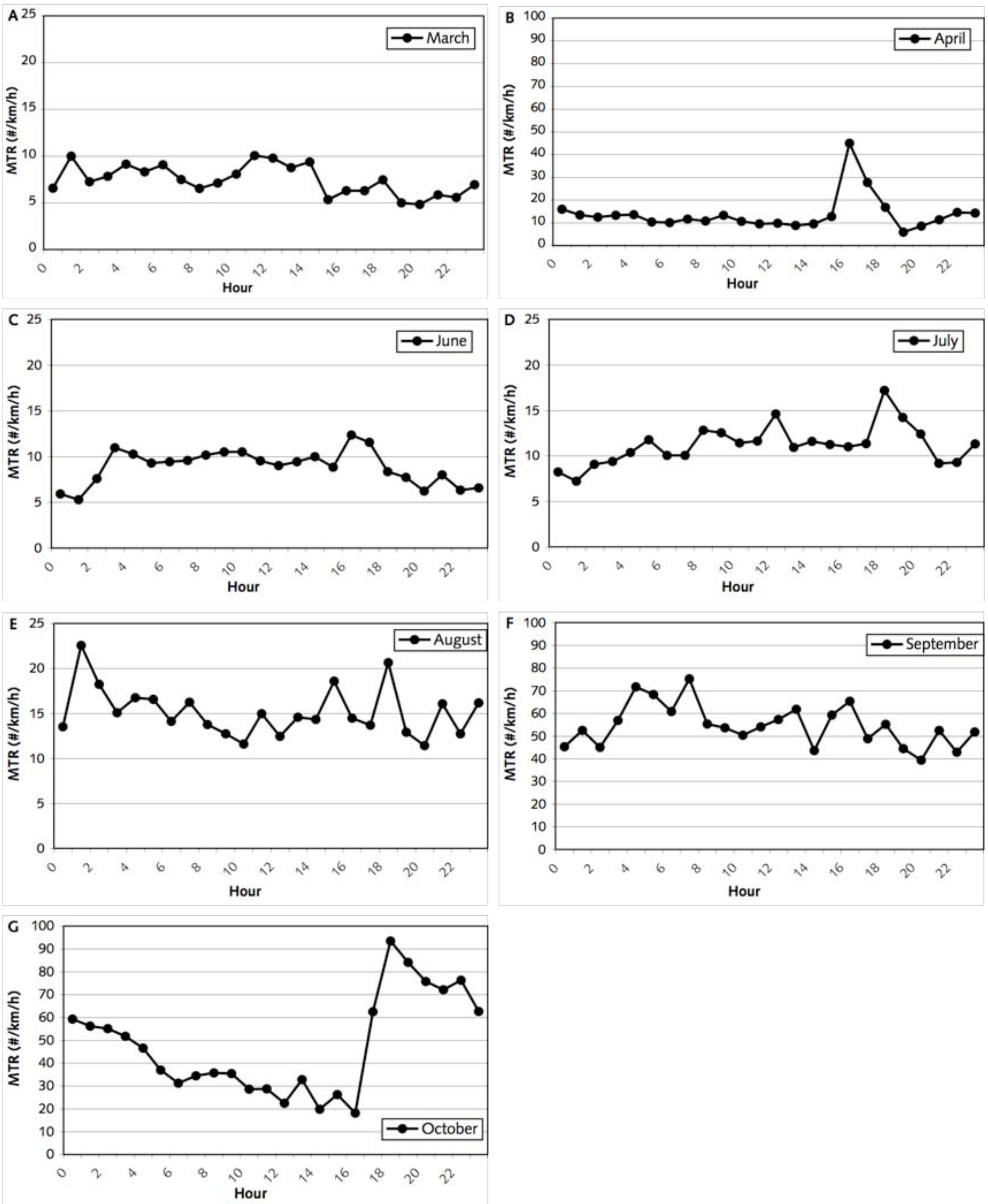

Figure 4.3 Diurnal patterns in mean traffic rate (MTR in #/km/hr) for the different months reported (A-G). Data averaged for the entire month. Note the differenced in scale.

Flight activity within versus outside the wind farm

Flight activity within and outside the wind farm was evaluated by visually counting the number of echo tracks from the unprocessed Furuno screen on several days throughout the study period (see §2.4 for methodological details). Flight activity was on average higher outside than inside the wind farm (fig. 4.4), although the difference was overall not significant (paired T-test, T=1.87 df=7 P=0.1) The result is similar to the patterns found in the visual observations (see figs. 4.5 & 4.6). Only in September were more birds counted within the wind farm. Visual observations on that day give no indication as to why flight activity within the wind farm was relatively high that day.

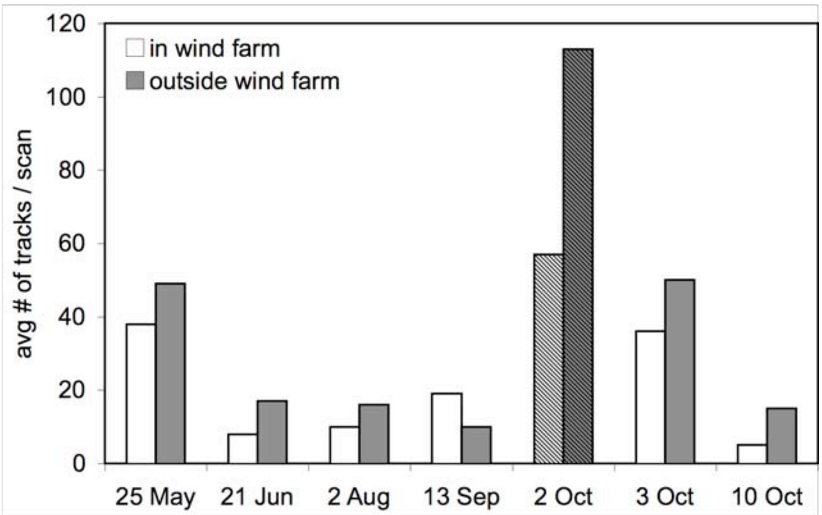

Figure 4.4 *Average number of tracks recorded within versus outside the wind farm. Dashed bars on 2 Oct reflect nocturnal data. Numbers reflect spot samples (i.e. per scan) taken from the horizontal Furuno radar. Data collected in two 90° angles from the metmast.*

4.2 Species-specific patterns (from visual observations)

Panorama scans were carried out each hour during observation days on the metmast (see §2.2.1) and give an impression of the species flying in the wind farm area, as well as the abundance of these species and their flight directions and altitudes. Data from these panorama scans are described in this paragraph, along with data from additional observations on flight behaviour of species present in the area.

4.2.1 List of species encountered during visual observations

A total of 49 species were seen during fieldwork at the metmast (table 4.2). These include harbour porpoise and grey seal. Other species are all birds.

Table 4.2 List of bird and mammal species seen during field work at the metmast in 2007, shown per month.

group	species	Jan	Feb	Mar	Apr	May	Jun	Aug	Sep	Oct
divers	black-throated diver				x					
	diver spec.									x
tubenoses	northern fulmar								x	
gannets	northern gannet		x		x				x	x
cormorants	great cormorant		x	x	x	x	x	x	x	x
geese & swans	swan spec.									
	dark-bellied brent goose		x		x					x
sea ducks	common scoter			x	x			x	x	x
	eider		x							
other ducks	duck spec.							x	x	
	Eurasian wigeon									x
	northern pintail									x
	red-breasted merganser				x					
waders	bar-tailed godwit									x
	calidris spec.			x						
	Eurasian curlew									
	redshank					x				
	wader spec.							x		
	woodcock								x	
skuas	arctic skua									x
	great skua									x
	skua spec.							x		
gulls	black-backed gull spec.			x	x		x	x	x	x
	great black-backed gull			x	x		x	x	x	x
	gull spec.				x		x		x	x
	herring gull		x	x	x	x	x	x	x	x
	large gull				x	x	x	x	x	x
	lesser black-backed gull			x	x	x	x	x	x	x
	Medit. yellow-legged gull							x		
	black-headed gull			x	x	x		x	x	x
	common gull			x	x	x	x		x	x
	kittiwake									x
	Sabine's gull									x
	small gull									x
	little gull				x					
terns	common tern							x		
	common/arctic tern							x	x	
	sandwich tern				x		x	x	x	
	tern spec							x		
alcids	guillemot								x	x
	razorbill									x
	razorbill/guillemot			x						x
raptors & owls	marsh harrier							x		
	peregrine falcon							x		x
	sparrowhawk									x
landbirds	grey heron				x		x	x	x	
	homing pigeon								x	
	jackdaw									x
	blackbird							x		x
	fieldfare									x
	redwing									x
	song thrush									x
	starling		x		x		x			x
	thrush spec.									x

Table 4.2 Continued.

group	species	Jan	Feb	Mar	Apr	May	Jun	Aug	Sep	Oct
(landbirds)	black redstart									x
	blackcap									x
	chaffinch									
	chiffchaff				x					x
	gold crest									x
	grey wagtail									x
	meadow pipit			x	x				x	x
	northern wheatear									x
	pied wagtail								x	
	pipit spec.								x	
	robin									x
	skylark									x
	swift							x		
	willow warbler/chiffchaff			x	x					
sea mammals	harbour seal	x							x	
	grey seal								x	
	harbour porpoise							x	x	x

4.2.2 Species-specific flight activity (panorama scans)

Species and abundance

The total amount of birds was relatively low in all seasons (table 4.3). The mean total density never exceeded 1 bird per km^2 and the maximum density of single species was 0,5 birds per km^2. Overall, the most common species were great cormorant, herring gull, lesser black-backed gull, kittiwake and unidentified (large) gulls (all > 0,1 birds/km^2). Scoters, divers and alcids were absent or very scarce. Highest numbers of herring gull were present in spring. Great cormorant, lesser black-backed gull and the unidentified large gulls were most numerous in summer and kittiwakes were only present in autumn. Terns turned out to be rather scarce throughout the period. Compared to the baseline situation (Krijgsveld *et al.* 2005) the densities were lower overall.

Table 4.3 Species composition and mean density (number of birds per km²) as observed during panorama scans. Maximum densities are bold. For each season the respective number of scans is given in brackets.

			mean density (birds/sqr. km)			
group	subgroup	species	spring (n=36)	summer (n=35)	autumn (n=57)	total (n=128)
alcids		Razorbill/Guillemot			**0,00**	0,00
cormorants		Great Cormorant	0,03	**0,23**	0,11	0,12
gannets		Northern Gannet	0,00		**0,07**	0,03
geese & swans	branta geese	Dark-bellied Brent Goose	**0,02**			0,00
gulls	large gulls	black-backed gull spec.	**0,05**	0,00	0,02	0,02
		Great Black-backed Gull	0,06	0,00	**0,09**	0,06
		Herring Gull	**0,50**	0,09	0,03	0,18
		large gull	0,11	**0,19**	0,08	0,12
		Lesser Black-backed Gull	0,15	**0,21**	0,09	0,14
	little gull	Little Gull	**0,00**			0,00
	small gulls	Black-headed Gull	0,02	**0,04**	0,00	0,02
		Common Gull	0,00	0,00	**0,01**	0,01
		Kittiwake			**0,24**	0,11
		Sabine's Gull			**0,00**	0,00
	unidentified gulls	gull spec.	0,00		**0,04**	0,02
landbirds	medium passerines	Blackbird			**0,00**	0,00
		Redwing			**0,00**	0,00
		Song Thrush			**0,00**	0,00
		Starling		0,00	**0,00**	0,00
		thrush spec.			**0,03**	0,01
	other large birds	Grey Heron		**0,00**		0,00
		Homing Pigeon			**0,00**	0,00
		Jackdaw			**0,01**	0,00
	small passerines	Meadow Pipit			**0,00**	0,00
		pipit spec.			**0,00**	0,00
other ducks	mergansers	Red-brested Merganser	**0,00**			0,00
	unidentified ducks	duck spec.		**0,00**		0,00
raptors & owls	raptors	Marsh Harrier		**0,00**		0,00
		Northern Goshawk			**0,00**	0,00
sea ducks	sea ducks	Common Scoter	**0,01**	0,00	0,00	0,00
terns	terns	Common/Arctic Tern		**0,00**	0,00	0,00
		Sandwich Tern	0,00	**0,04**	0,02	0,02
tubenoses	tubenoses	Northern Fulmar			**0,00**	0,00
waders	waders	calidris spec.	**0,01**			0,00
		Eurasian Curlew		**0,00**		0,00
Total birds			0,96	0,82	0,86	0,87

Distribution of species in the wind farm area

The distribution of birds around the metmast is visualised is figure 4.8. Overall the highest numbers were present in sector 2 (west-north-west). Lowest numbers were recorded in sector 8 (north-north-east). Among the most abundant subgroups, gannets showed the strongest variation in their distribution, with almost no birds in the north-westerly sections and highest numbers is the west-south-westerly sections. This species also showed strong avoidance of the wind farm (see §5.2). The relative high numbers of small gulls in sector 2 (east-north-east) is due to high numbers of kittiwakes foraging in this area close to the metmast in autumn.

The distribution pattern shown in figure 4.5 appears to be influenced by the presence of the wind farm. The distribution within versus outside the wind farm is shown for each species in figure 4.6. This figures shows that overall, less than 25% of all birds were recorded inside the wind farm. This proportion is remarkably high, given that the wind farm covers close to 50% of the scanned area. This indicates that birds were avoiding the wind farm, which result is similar to results from the radar observations shown in §4.1. Again, particularly gannets showed a strong preference for the area outside the wind farm.

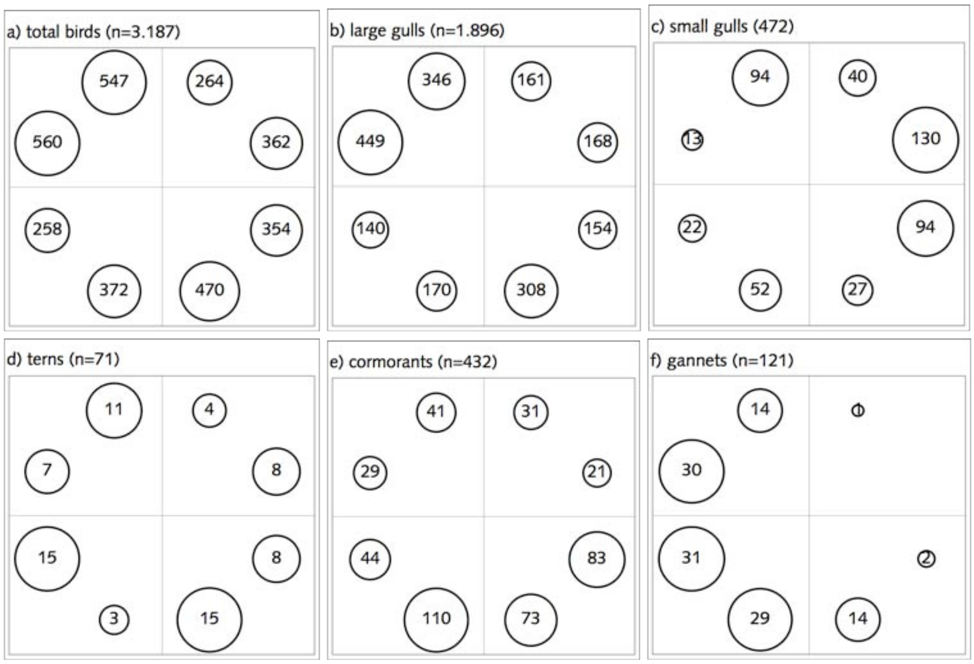

Figure 4.5 Distribution of birds around the metmast (situated in the centre) as being observed during panorama scans. The wind farm is situated in the upper right diagonal. Source: panorama scans period February-October.

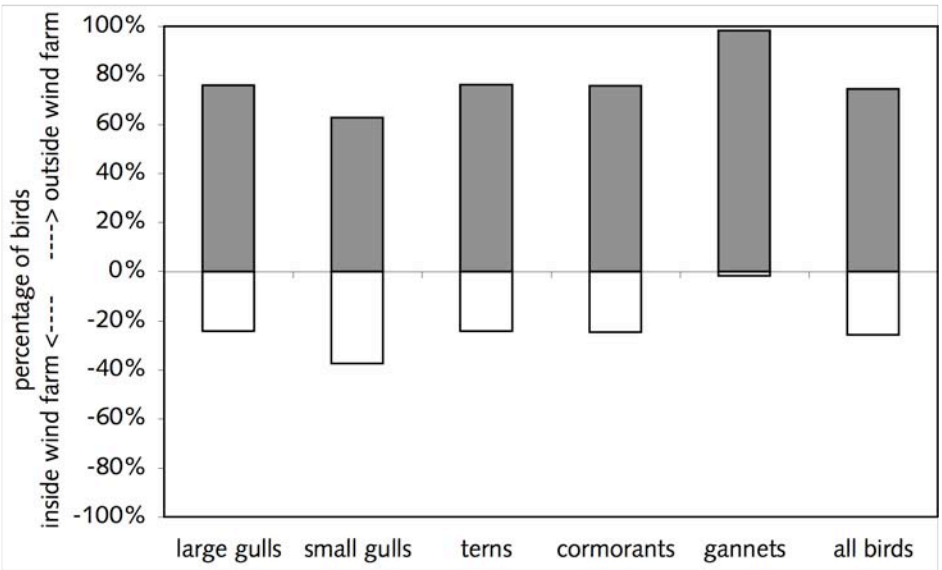

Figure 4.6 Relative distribution of several species within and outside the wind farm. Given the layout of the wind farm within the covered area, the proportion of birds inside the wind farm should be 50% when no avoidance occurs (dotted line). Source: panorama scans February-October 2007). Note that all species occurred in higher percentages outside the wind farm.

Number of birds inside versus outside the wind farm

To investigate the distribution of bird species present in the area in relation to the wind farm, paired observations were made along transect lines within and outside of the wind farm (see §2.2.1). The results of these counts are shown in table 4.4. Main interpretations are listed below.

- In contrast to the panorama scans, the paired observations do not show a reduced **overall flight intensity** inside versus outside the wind farm.
- In closer detail, **large gulls** and **gannets** tended to avoid the wind farm. This corresponds with figure 4.6. The result for large gulls is surprising, as they did not seem to show deflection in their flight paths, and were regularly seen flying through the wind farm. As large gulls were often flying locally in the area, the distribution may change when locally flying birds are included in the analysis as well (final report 2009).
- For **cormorants** and **terns** there was no clear difference
- For **small gulls** the opposite pattern is demonstrated: the paired observations show, in contrast to figure 4.6, that small gulls were more abundant within the wind farm. This pattern is mainly due to high numbers of kittiwakes that were present in the wind farm during a single observation day in October.

4.3 Nocturnally flying species

Calls registered in the night of 2-3 October 2007 were from blackbirds and song thrushes mainly, as well as redwings. Calls were recorded throughout the night, from 20:00 until 6:00 h. A peak in call frequency was recorded in the early morning hours, around 5:30 h. At this time, up to 90 calls were heard per 5 min interval. Thrushes were also seen in a three 10-minute moonwatching sessions between 22:00 and 23:30 h (half moon). Data will be analysed in more detail when data from the spring and autumn migration periods in 2008 are available as well.

Table 4.4 Overall flight intensity (number of birds per hour) inside and outside the wind farm. Flight intensities are shown in number of birds per hour. Intensities of 0 are left blank. Differences > 150% are marked in italic. Source: paired observations period February-October 2007.

group	subgroup	species	flight intensity inside	flight intensity outside
cormorants		great cormorant	4,38	4,19
divers		black-throated diver		0,03
gannets		northern gannet	0,07	0,96
geese & swans	branta geese	brent goose	0,25	0,80
gulls	large gulls	black-backed gull spec.	0,22	1,16
		great black backed gull	0,90	1,60
		herring gull	1,33	1,30
		large gull	0,86	3,03
		lesser black-backed gull	2,19	1,70
		meditt. yellow-legged gull	0,04	
	small gulls	*black-headed gull*	*0,29*	*0,13*
		common gull	*0,36*	*0,10*
		kittiwake	*6,25*	*2,10*
		small gull		0,03
	unidentified gulls	gull spec.	0,04	0,07
landbirds	medium passerines	redwing	0,11	
	other large birds	grey heron		0,03
		jackdaw		0,07
	small passerines	chiffchaff	0,07	
		grey wagtail		0,03
		skylark		0,03
		swift		0,07
other ducks	swimming ducks	Eurasian wigeon	0,18	
sea ducks		common scoter	0,04	0,13
skuas		skua spec.		0,03
		arctic skua	0,04	
		great skua		0,03
terns		sandwich tern	0,25	0,20
waders		Calidris spec.	0,11	
totals				
		large gulls	5,53	8,78
		small gulls	*6,90*	*2,36*
		terns	0,25	0,20
		cormorants	4,38	4,19
		gannets	0,07	0,96
		all birds	17,96	17,83

5 Results on flight paths

In this chapter, data are presented on flight paths of birds, *i.e.* flight directions and behavioural responses in flight activity to the wind farm. This is shown by means of observations made with the horizontal radar on the one hand, showing flight paths around the wind farm area on a larger scale (§5.1). On the other hand, data are shown for individual species observed in the area during field work (§5.2).

5.1 General patterns from horizontal radar data

Data shown
Flight paths were recorded continuously (24 hours per day, seven days per week) through the Merlin system operating on the horizontal radar. The baseline study showed that sea clutter largely contaminated the horizontal radar data on flight paths (Krijgsveld *et al.* 2005). Because of this, emphasis was laid during the reported study period on improving data collection through improved Merlin settings and data calibration.

For the report at hand, only part of the data was analysed (see § 3.2.2). From each of the seasons, specific days were selected for analysis (table 5.1). On these days, weather conditions were calm and waves were low, thus minimizing the amount of sea clutter in the database. Furthermore, days were selected from which flight activity was known (from visual observations), allowing critical evaluation of the radar data. For comparison, days adjacent to calm observation days were also analysed.

Table 5.1 Overview of dates for which horizontal radar data were analysed. 'Observation' gives the day of that month on which a visual observation at the metmast was carried out.

season	month	day	obs.date	season	month	day	obs.date
spring	May	23-26	25	autumn	September	5-7	6
summer	June	8				12-14	13
		19-23	21		October	1-4	night 2-3; 3
	July	31				9-11	10
	August	1-4	2			24-27	25
		19-21	20		November	1-3	2

Main flight patterns through the seasons
Main flight patterns thus obtained are depicted in figures 5.1 to 5.3. Below we discuss the results per season.

- Data from **spring** are limited, because the system was still being set-up and tested extensively at that time. Data shown are from the end of May only (May 25 2007, fig. 5.1). No pattern is visible of birds migrating north-east. During daytime observations on these days, no obvious migration occurred. Some terns were seen, foraging in the area whilst migrating north. Otherwise, activity was most of gulls. No visual data are available for the nights. Nocturnal visual observations at the metmast are planned for the spring of 2008. During night time, activity of gulls is much lower than during daytime. Because during the night, data are thus much less obscured by 'random' flight paths of gulls, patterns of migrating birds should emerge clearer at night than during daytime. However, the data show no evidence of north-easterly flight movements. Wind direction varied. On the night of 25-26 May wind was N and unfavourable for migration, but the night before that it was S to SE and favourable for migratory activity.

- During the **summer** months, flight directions tended to show a west-south-westerly trend (21 June 2007, fig. 5.2). Gulls formed the major part of birds present in the area at that time, and it is therefore surprising that flight paths seemed to show a specific direction. Gull movements are largely determined by presence of fishing vessels (Krijgsveld *et al.* 2005), which is why flight directions are more or less random. Whether changes in flight direction were present in the course of the day, will be analysed for the final report. Possibly the data reflect gulls flying towards the breeding colonies in IJmuiden. Interestingly, the figure for the night of the 21st shows very little flight activity, in correspondence with low nocturnal activity at sea in the breeding season. Bird activity on the 21st of June was low, and consisted mainly of movements of gulls and cormorants. Whether was calm with variable winds and a calm sea. A similar results was visible on the 20th of August (fig. 5.3). Nocturnal activity on this date was higher, possibly reflecting the onset of autumn migration.
- Migration in the **autumn** months was oriented south-west to west (from visual observations and Furuno radar screen). This pattern did indeed emerge from the radar data, for those nights and days on which the sea was calm and winds were a favourable NE. Flight directions are shown for the 13th of September (fig. 5.4) and for the 25th of October (fig. 5.5). For the 13th of September, no clear migratory pattern was visible. Winds were southerly on this day, and unfavourable for migration. On October 25th, winds were easterly, and reasonably good for migration. Flight activity was oriented SW. During the day, this pattern was confounded by 'randomly' flying gulls. At night, the pattern became more outspoken, with almost entirely SW-oriented flight paths outside the wind farm. Closer to the wind farm, and inside it, flight paths were oriented in different directions, possibly reflecting birds adjusting their flight paths to the presence of the wind farm, and flying around it.

General observations

- The data for the night of October 25 suggest that some **avoidance** of the wind farm was occurring, visible in the flight directions N and NW of the wind farm versus those W and SW to the wind farm. Whether avoidance actually did occur needs to be analysed in further detail in the following phase of the study, e.g., by means of analysis of deviations from the mean flight direction.
- Flight **directions differ largely inside versus outside** the wind farm. Especially on nights with high migratory activity, this pattern was clear. Outside the farm, birds flew generally SW, but inside the wind farm and closely around it, flight directions varied largely.

• Flight activity tended to be **higher in the gap between turbines WT9 and WT10** (see fig. 2.2 on p. 12). Whether these two patterns are due to actual differences in flight paths, or to detection limitations in the farm (especially of smaller migrating birds) and clutter problems, remains to be analysed in the following phase of the study (2009).
• When data were combined over several days, the patterns were obscured. This is possibly due to increasing amounts of clutter on days with less favourable seas, as well as predominant 'random' flight movements of gulls on days with little migratory activity. For comparison, an photo is included made of the Furuno screen, taken on the night of 2-3 October 2007 (fig. 5.7). This shows that migratory activity was high, much higher than was recorded by Merlin. It also shows that the flight paths of migratory birds covered the wind farm area as well. Migration at that moment was almost entirely of thrushes (blackbirds, song thrushes, redwings), flying at altitudes above the wind farm. Flight activity was much higher than in the summer months, especially at night time (see chapter 4). This is reflected in the colour of the graphs.
• Detection was in all seasons highest closest to the wind farm. Because in the summer months flight activity is mostly of gulls, detection limitations should occur well beyond 3 NM. Decrease in bird numbers at larger distances from the radar in the summer months, suggests that sea clutter was also present in these data. The effect was indeed much less pronounced in the visually analysed data (see fig. 5.8), where clutter was absent from the database.

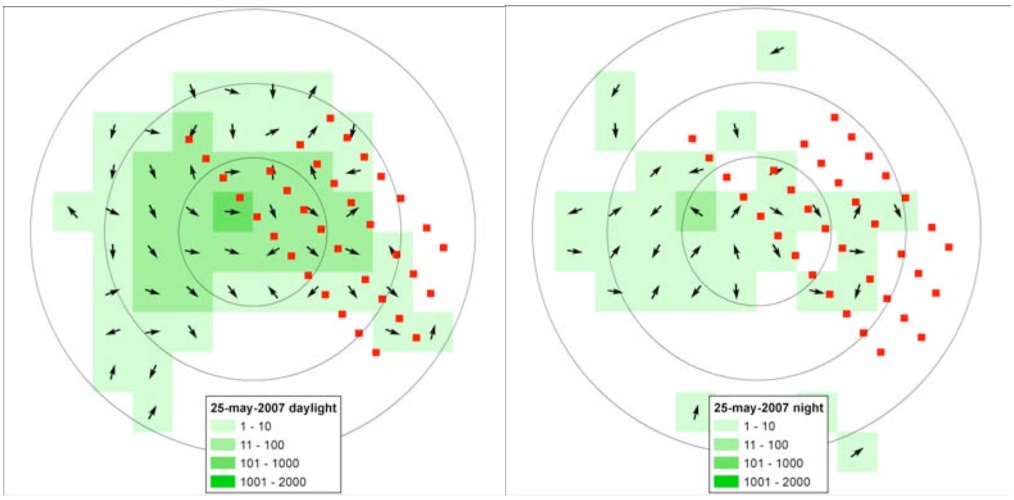

Figure 5.1 Flight paths on May 25 2007, during day (left) and night (right). Data are averaged per grid cell of 1km². Arrows depict average flight direction per cell, green colour shades depict the number of tracks recorded per cell. Centre = metmast, red squares = turbines, lines = 1NM intervals.

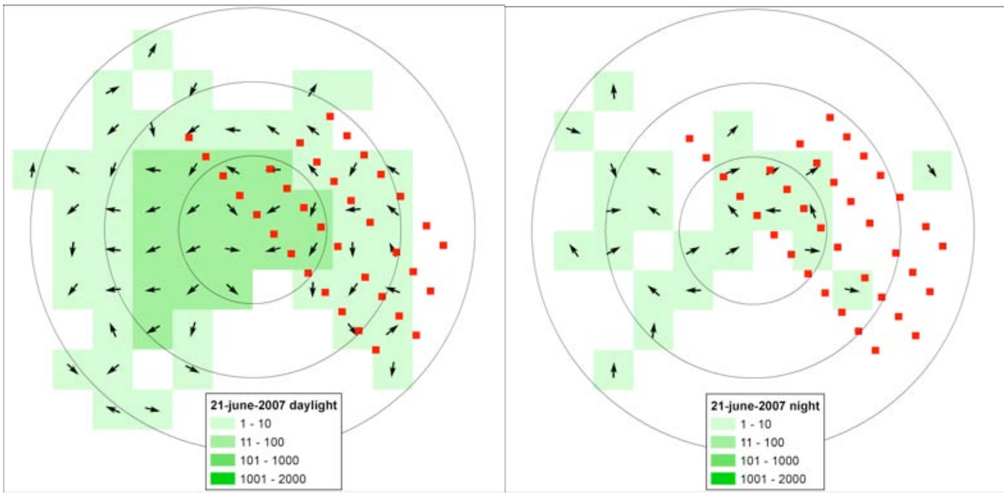

Figure 5.2 Flight paths on June 21 2007, during day (left) and night (right). Legend see fig. 5.1.

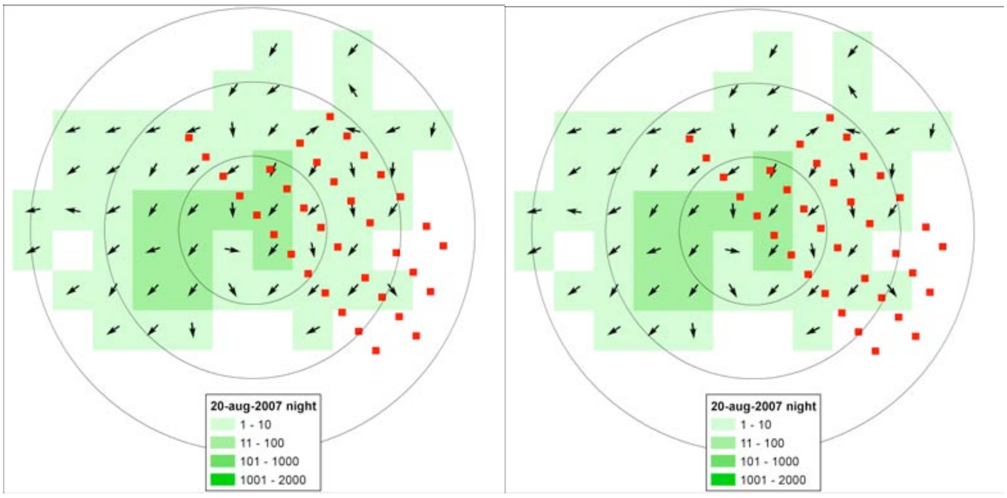

Figure 5.3 Flight paths on August 20 2007, during day (left) and night (right). Legend see fig. 5.1.

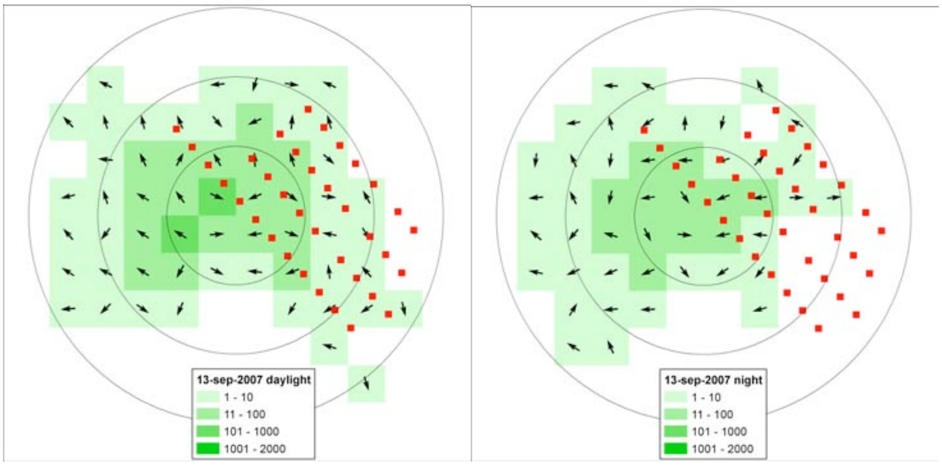

Figure 5.4 Flight paths on September 13 2007, during day (left) and night (right). Legend see fig. 5.1.

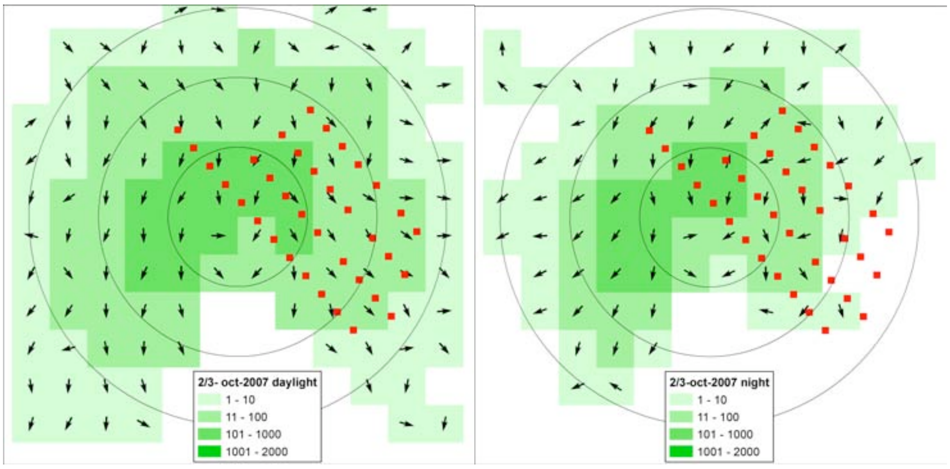

Figure 5.5 Flight paths on October 2&3 2007, during day (left) and night (right). Legend see fig. 5.1.

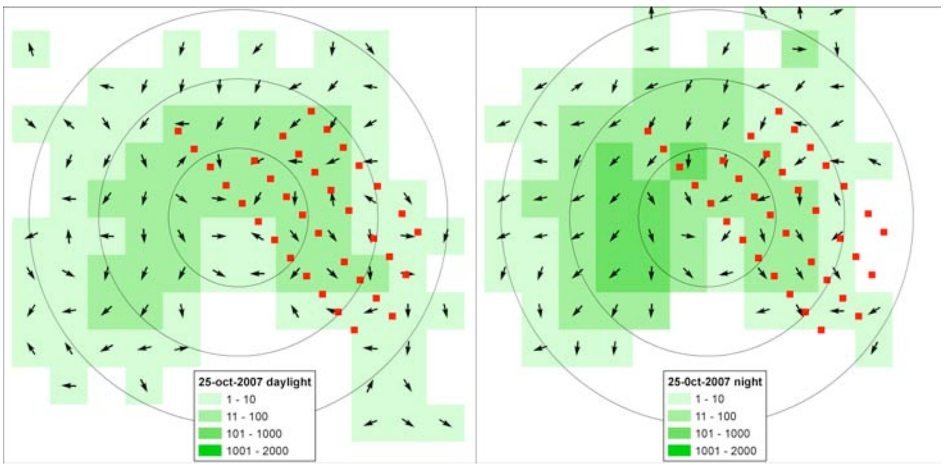

Figure 5.6 Flight paths on October 25 2007, during day (left) and night (right). Legend see fig. 5.1.

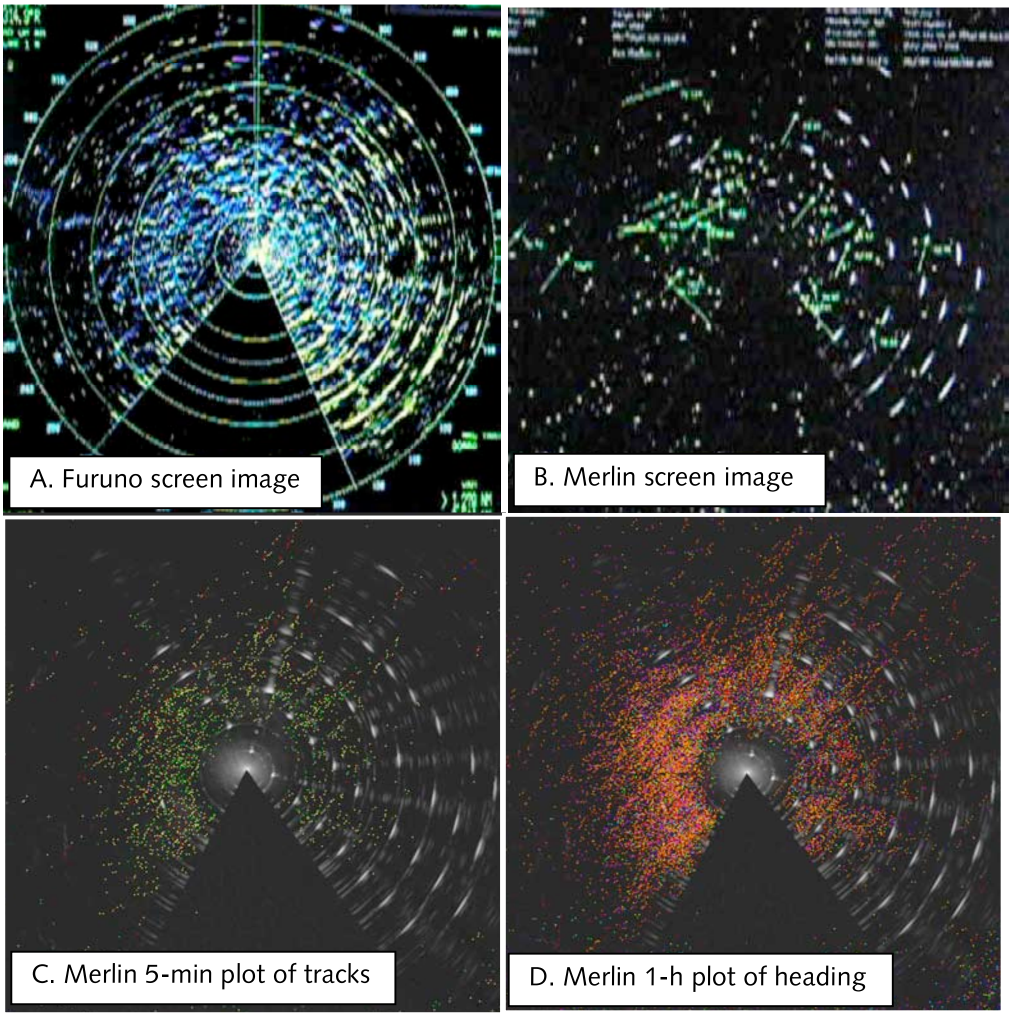

*Figure 5.7 Comparison of data as seen on Furuno and as processed by Merlin. Shown are screen images of Furuno screen (**A**, raw radar data, bird tracks shown as blue lines) and Merlin screen (**B**, processed radar data, bird tracks shown as green dots, with the line indicating flight direction). To mimic the blue echo trail as visible in A, all tracks recorded by Merlin over a period of 5 min are shown (**C**; each dot is (part of) a track; 19:40-19:45). To visiualise heading as recorded by Merlin, headings of all data recorded during 1 hour (19:00-20:00) are shown in colors (**D**; each dot is (part of) a track); orange is SW, pink is W) Echoes reflect thrush migration at 19:30 on October 2 2007. Note that Merlin recorded less tracks than were seen on Furuno, but in the same SW-direction. Based on these results a.o., Merlin settings were changed end October to increase number of echoes tracked. Note also that detection was limited to 1,5 NM distance for thrushes.*

Patterns from Furuno raw radar

In comparison to the data presented above, which originate from the horizontal radar data as recorded by Merlin, we visually recorded data from the Furuno radar screen. These data give an accurate image of flight paths of birds, because visually, clutter and birds can easily be recognized and respectively be excluded from or included in the data. However, the analysis is limited to those days on which visual observations were done at the metmast, and only a limited number of scans has thus far been analysed for this database.

Densities of flying birds were higher in the gap in the NW of the wind farm between WT9 and WT10, as well as in the area just north of the main body of the wind farm. This pattern, similar to the above presented data from the Merlin database, suggests occurence of deflection of flight paths away from the wind farm and a preference to pass the wind farm not through the main body. Clutter effects are excluded in these patterns because tracks were recorded visually. Detection limitations may play a role, but this effect will be minor, because data are summarized for various months, and thus smaller migratory species with a smaller detection range form only a limited percentage of all birds.

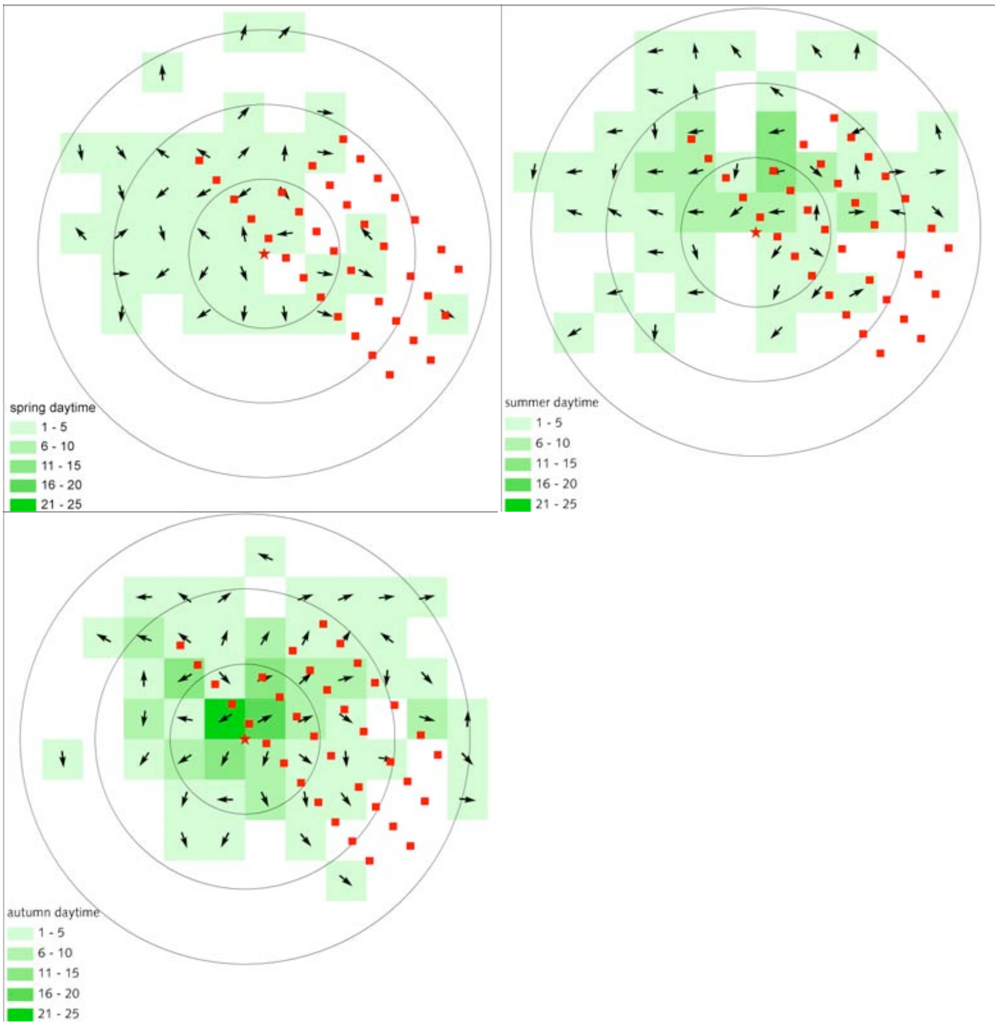

Figure 5.8 Average flight directions and numbers of flight paths, during daytime, in spring (May 25), summer (June 21, Aug 2) and autumn (Sep 13, Oct 3&10), as recorded visually from raw, unprocessed radar images. Legend see fig. 5.1. Data from a limited number of radar scans per day.

5.2 Species-specific patterns (from visual observations)

In this paragraph, data are presented from visual observations, describing species-specific patterns that were not discernable from the Merlin radar data.

5.2.1 General flight directions of species present

Mean flight directions

The mean flight direction of the most common species groups as were observed in the panorama scans is visualised in figure 5.9. Overall flight directions towards north-west were dominant. This overall pattern is mainly caused by high numbers of large gulls flying in this direction. In spring (morning 5th April 2007) a group of 200 herring gulls was recorded flying towards NW. Small gulls (although less numerous) tended to move towards south-west and gannets towards north. The overall flight patterns of terns and cormorants were less distinctive (in all seasons). This is mainly due to the foraging behaviour of both species. Cormorants flew in different directions within the study area, looking for food. Also terns, despite the fact they were migrating northward along the coast, were foraging on their way, which is reflected in their recorded flight paths.

Variation through the season

As flight directions are strongly influenced by the annual cycle of concerned birds, we expect to see variation throughout the season. Figure 5.10 illustrates that the dominant flight direction in spring was north-west. Although the total number of birds was much lower within the wind farm, the pattern holds true for this area as well. In summer the overall flight direction outside the wind farm was towards south-west. Within the wind farm, the dominant direction tended to be south-east, but the pattern shows no strong directionality. Finally, in autumn flight directions were more evenly distributed outside as well as inside the wind farm.

Migratory patterns

An overall migration pattern towards south-west, as expected, was not recognised. Instead, a dominant flight direction towards north even emerged. Especially gannets and large gulls contributed strongly to these northerly flight directions. Most of these movements were recorded in September. In this period the direction of gannets along the Dutch coast generally is variable (Camphuysen & van Dijk 1983), driven by food supply and wind force and direction. During panorama scans at the metmast high numbers of gannets were observed with northern wind directions.

Marsh harrier on southbound migration in August (Photo: H. Prinsen)

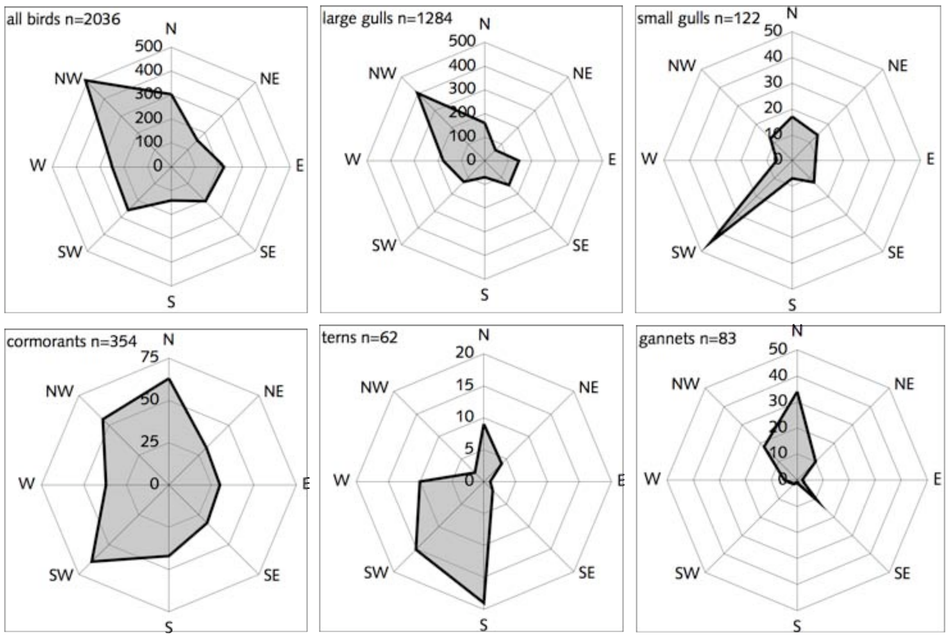

Figure 5.9 Distribution of flight directions of all birds and of species that were most common in the panorama scans, during daytime and for all seasons combined.

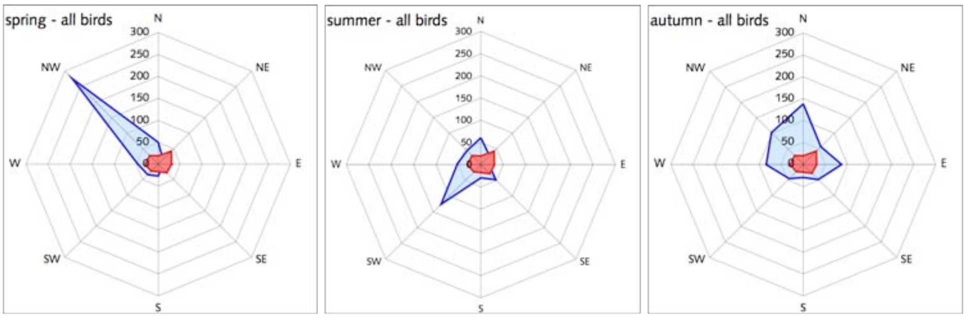

Figure 5.10 Distribution of observed flight directions in spring, summer and autumn within the wind farm (red polygons) and outside it (blue polygons), as observed in the panorama scans.

Diurnal variation in gull flight directions

The flight direction of large gulls is not only variable throughout the year but also during the day. In the early morning (until 2 hours after sunrise), large gulls predominantly flew westward in spring, and east/south-east in summer and autumn. In the late afternoon large gulls tended to fly south in autumn. In spring and summer the number of large gulls was very small in the late afternoon.

5.2.2 Flight paths through the wind farm

Flight paths of individual birds that were flying through the wind farm, were followed to establish how they adjusted their flight path to the presence of the wind farm. Flight paths of various species were thus recorded, of a limited number of birds. The data set will be extended during field work in 2008, to gain better insight in species-specific responses to the wind farm.

Flight paths were recorded of more than 150 birds and bird groups. Recorded flight paths are visualised in figures 5.11 and 5.12. A few patterns emerge from these data.

- First, flight paths appear to be **concentrated** in the NW corner of the wind farm, between WT9 & WT10. This observation suggests that possibly birds were avoiding the main body of the wind farm, but did cross the single line of turbines. The line extends 2 km from the main body of the wind farm, so these birds are saving over 4 km of flight. For example, gulls (herring gull, kittiwake) were seen following this route, as well as flocks of starlings and thrushes on autumn migration, twice a flock of ca. 20 brent geese, and a black-throated diver.
- Second, several flight paths could be recorded of birds **avoiding the entire wind farm**, including the single line in the north-western part of the wind farm. Due to the large distance from the observation platform, these groups generally could not be identified. Gannets were regularly seen doing this, as well as a black-throated diver, a flock of redwings, a flock of 22 brent geese, two individual guillemots.
- Birds that were flying through the wind farm, did not always remain in one single corridor (the area between two rows of turbines), but were regularly seen **changing between corridors**, by changing their flight direction (e.g. flocks of starlings and

thrushes in autumn, a blue heron). birds that did stay in one corridor, were mostly larger gulls (herring gull, black-backed gulls). Also, flight paths were not equidistant from the turbines between which they flew. These data are in contrast to results reported from the Horns Rev and Nysted wind farms in Denmark (Petersen *et al*. 2006), where birds were largely flying through the corridors. Some birds maintained their course once inside the wind farm, irrespective of corridors, with occasional small deflections to avoid single turbines (flocks of starlings). Some birds did stay within a specific corridor, and changed back to their original flight direction after exiting the wind farm (flock of curlews).

- Bird groups often were seen '**hesitating**' to enter the wind farm. Flight paths would follow the edges of the wind farm for some km before entering. Often, groups were seen entering the wind farm there where the nearest **turbine was standing still** (correlation to be analysed in 2008).
- **Cormorants** were seen in increasing numbers from the start of the study through the summer period. At the end of the breeding season, numbers decreased markedly. The metmast was used as a resting place, as well as the platform to the north of the wind farm. The birds flew through the wind farm on a regular basis, often using the turbine platforms as a resting place.
- **Gannets avoided** the vicinity of the wind farm. Ca. 40 birds were observed flying around the entire wind farm or deflecting upon approaching the wind farm. A total of six birds were seen entering the wind farm. E.g., on one occasion (25 October 2007), three foraging gannets were individually seen approaching the wind farm. One turned around when approaching the wind farm to ca. 100 m. Another entered the wind farm, turned and flew out again, two turbines to the side. The third gannet entered the farm, circled, and exited again without flying beyond the first row of turbines.
- A **peregrine falcon** was seen on several occasions, as well as an arctic and a greater **skua**. The peregrine falcon (unclear if observations concern one individual or different birds) chased migrating passerines, outside as well as inside the wind farm without showing changes in flight path upon entering the farm. It was seen to use the metmast (with observers were present) as well as turbine platforms to sit. Two skuas similarly were seen flying through the wind farm without apparent effect on flight paths.
- Data on **changes in flight altitude** in relation to the wind farm are currently too limited for interpretation. Further data on this aspect will be collected during field work in 2008 and presented in the final report.

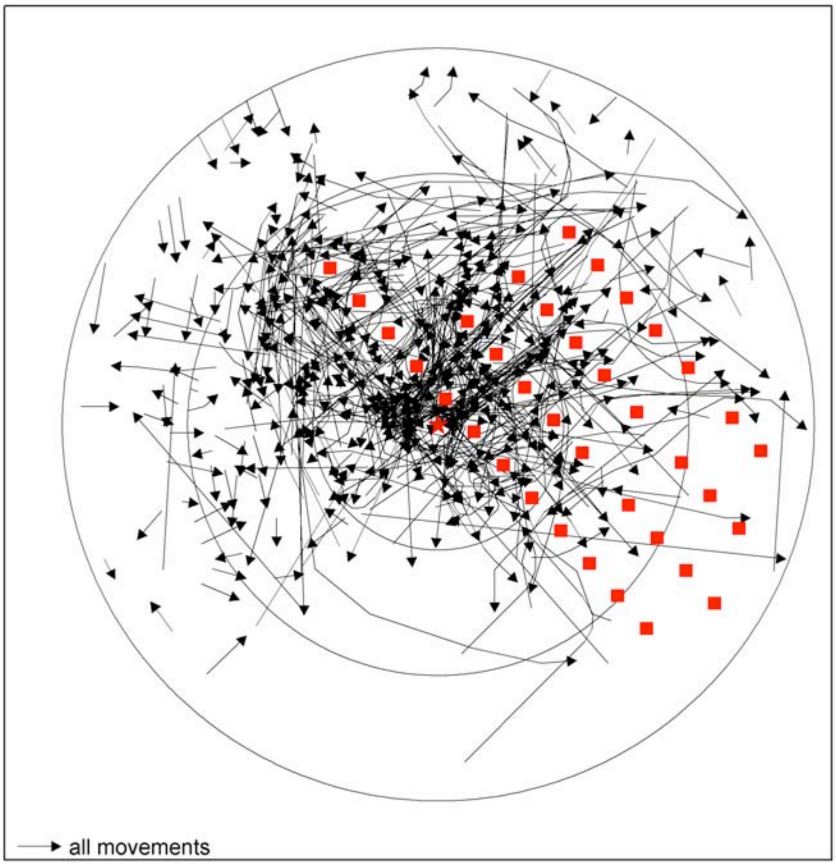

Figure 5.11 Flight paths of individual birds of various species flying through the wind farm. Data visually recorded from the metmast (star). Squares depict the turbines, rings are placed at 1 NM intervals. Observations do not cover SE part of wind farm well, due to distance.

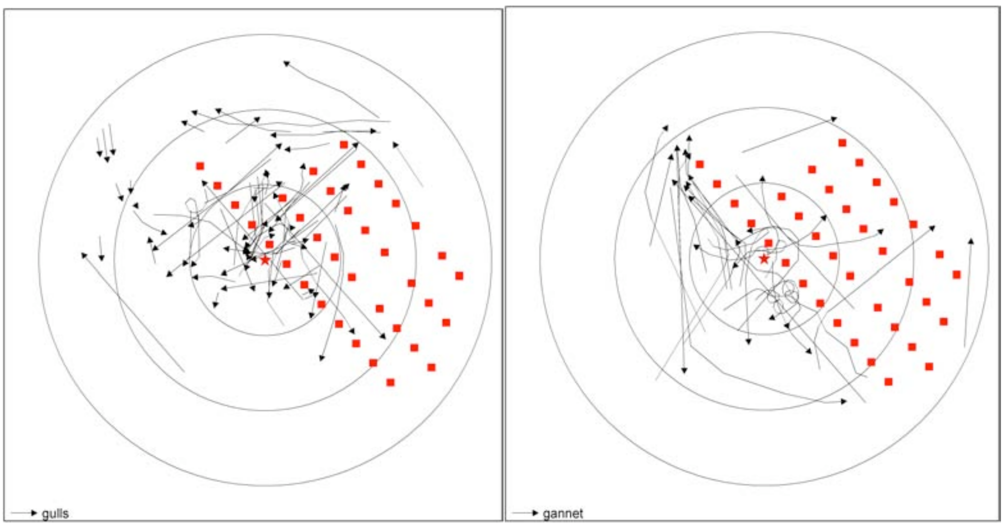

Figure 5.12 Flight paths of gulls (left) and gannets (right) flying in the wind farm area. Data visually recorded from the metmast (star). Squares depict the turbines, rings are placed at 1 NM intervals. Note the low level of avoidance in the gulls, versus the high level of avoidance in the gannets.

The species for which flight paths were recorded are summarised in table 5.2, along with information on the occurrence of deflection. As the flight paths were recorded mainly to establish how birds are flying though the wind farm, the number of birds recorded in the wind farm logically is higher than the number recorded outside the wind farm. This ration does not reflect actual densities of birds in and outside the wind farm. The number of bird groups that changed their flight path in response to the wind farm was overall similar to the number of bird groups that did not adjust their flight paths.

Regular visitors at the metmast: a peregrine falcon apparently foraging locally on songbirds in the wind farm area during the migratory period, and starlings taking a rest during their migration W to England. Photo's C. Heunks (peregrine) and K. Krijgsveld.

Table 5.2 *List of species of which flight paths were recorded, as well as the occurrence of deflection in flight paths in response to the wind farm. The list shows species of birds and mammals observed from the metmast between March and October 2007. The 1st column shows the total number of groups and the total number of individuals of which flight paths were observed (1st pair of columns). The 2nd pair of columns shows the occurrence of these groups within and outside the wind farm. The 3rd pair of columns shows whether observed groups showed deflection or not. Note that not for all groups deflection information exists.*

species name	# of groups	# of birds	# of groups outside OWEZ	# of groups inside OWEZ	# of groups showing no deflection	# of groups showing deflection
arctic skua	1	1	-	1	-	-
blackbird	3	25	-	3	1	1
black-headed gull	1	5	-	1	1	-
black- throated diver	1	1	-	1	-	1
dark-bellied brent goose	4	60	1	3	-	4
common gull	4	8	3	1	4	-
common scoter	3	3	1	2	1	2
common tern	2	4	-	2	1	1
cormorant	31	45	6	25	18	13
northern gannet	24	34	18	6	2	20
greater black-backed gull	11	11	3	8	5	6
greater skua	1	1	-	1	1	-
grey heron	3	4	1	2	1	2
herring gull	7	11	4	3	5	2
kittiwake	1	9	-	1	-	1
lesser black-backed gull	19	36	6	13	12	6
marsh harrier	1	1	-	1	-	1
meadow lark	1	1	-	1	1	-
meadow pipit	1	1	-	1	1	-
peregrine	2	2	-	2	2	-
redwing	3	47	1	2	1	-
sandwich tern	6	17	1	5	3	2
song thrush	1	1	1	-	-	1
starling	10	1376	-	10	2	5
auk/guillemot	1	1	-	1	1	-
black-backed gull spec	1	1	-	1	1	-
curlew/whimbrel	1	1	-	1	-	1
diver spec	1	1	-	1	-	-
duck spec.	1	1	-	1	-	1
large gulls spec.	3	150	1	2	3	-
swan spec.	1	1	1	-	1	-
wader spec.	1	1	1	-	1	-
thrush spec.	4	84	1	3	1	1
grey seal	1	1	-	1	-	-
harbour porpoise	8	12	6	2	6	1
harbour seal	1	1	-	1	1	-
overall birds	155	1945	50	105	70	71

6 Results on flight altitudes

In this chapter, data on flight altitudes of birds are presented. Overall flight altitudes of birds present in the wind farm area are described in §6.1. These data originate from measurements with the vertical radar, carried out in a range of ca 1,5 km (0.75NM) around the metmast, and therefore provide data on flight activity up to altitudes of ca. 1,5 km. In §5.2 data are presented on species-specific flight altitudes. These data are currently limited to much lower altitudes, as they were obtained by visual observations with the human eye. In the final report, species-specific observations will hopefully be available from moon watching during nights in the migratory periods (2009).

6.1 General patterns in flight altitude (from radar observations)

Risk at various altitudes

Bird migration takes places at a wide range of altitudes. During daytime, migration generally occurs at lower altitudes than at night. Different species groups also show large variation in general altitude up to which they migrate. Waders and thrushes can reach high flight altitudes, while marine birds generally remain at relatively low altitudes. In addition, flight altitudes vary significantly with weather conditions. Collision with wind turbines can occur when bird fly at rotor height, *i.e.* from 25 - 115 m. Birds flying close to these altitudes still experience a risk as flight altitudes may easily change depending on e.g. weather conditions or behavioural changes. Flight patterns of birds were therefore classified in four different altitude bands related to this risk (0–25 m medium risk; 25–150 m high risk; 150–250 m medium risk; above 250 m low risk). Birds generally flying above 250 m are considered to have a low collision risk. They may reduce flight altitude to turbine level in response to weather conditions (change to head winds, precipitation, air pressure).

Altitude distributions of birds

Figure 6.1 shows the altitude distribution at which birds fly during the different months of the study period, during the night and the day.

- During autumn migration, but especially in October, high numbers of birds migrated at high-risk altitudes (25-150 m) during the night. In the remaining months most flight movements at the high-risk altitude of 25-150 m took place during daytime, possibly reducing collision risk probably heavily because of better visibility of the turbines.
- The seasonal pattern of is more or less similar to results from the baseline study (Krijgsveld *et al.* 2005). In the summer months daily flight movements prevailed and most activity occurred at the lower altitudes. Numbers increased at high altitudes from August until October. During autumn migration, activity at high altitudes prevailed during the night and during the day highest flight activity took place at lower altitudes. High flight activity at high altitudes during the day in summer is probably due to insects. In 2008 improvements to Merlin and the dataset may enable successful filter of these false data. Fortunately, the occurrence of clutter form insects is limited because

Merlin generally does not seem to record insect tracks. These results will be discussed in the final report of this project to be published in 2009.

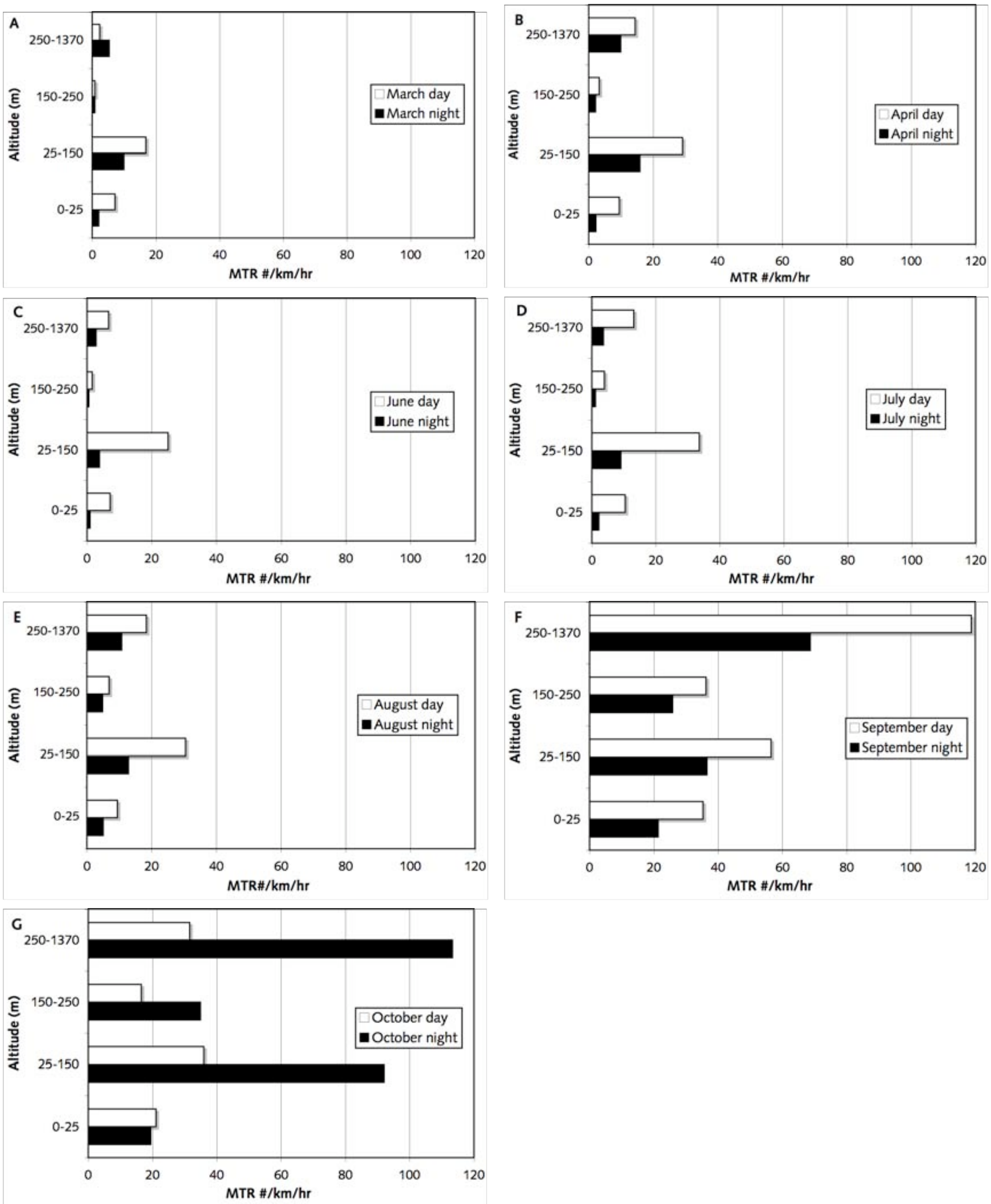

Figure 6.1 Mean traffic rate (MTR, in # of bird groups/km/hr) at different altitudes split between day and night for the different studied months. Note that altitude bands are not equal in size.

6.2 Species-specific patterns (from visual observations)

Dominance of gulls

Flight altitudes of birds are highly variable, depending on weather circumstances and behavioural activities, and therefore differ highly between species. Unfortunately the amount of data collected on different specific species is currently not high enough to allow an analysis of species-specific patterns.

Because large gulls were by far the most common species, the overall pattern is highly dominated by these species. The mean altitudes of flying birds are visualised in figure 6.1. The mean altitudes varied from 10 up to 50 meters. For most species, flight altitudes were on average comparable to flight altitudes measured in the baseline situation.

Great black-backed gull flying through the wind farm at rotor height. Photo M. Poot

Altitudes inside versus outside the wind farm

Mean flight altitudes tended to be (slightly) higher in the eastern sections (sector 5 to 8), inside the wind farm. Again this pattern was mainly caused by the mean flight altitude of large gulls in this area. Gannets showed the opposite pattern, with extreme low flight altitudes in the eastern sections and average altitudes in the other areas.

The pattern of flight altitudes of birds, as shown in figure 6.1, seems to be correlated to the presence of the wind farm. Mean flight altitude within versus outside the wind farm is shown for each species in figure 6.2. This figure shows that overall, birds tended to fly higher within the wind farm. The difference is most evident for large gulls. The opposite pattern is shown for gannets, which had lower flight altitudes near or in the farm than further away from it.

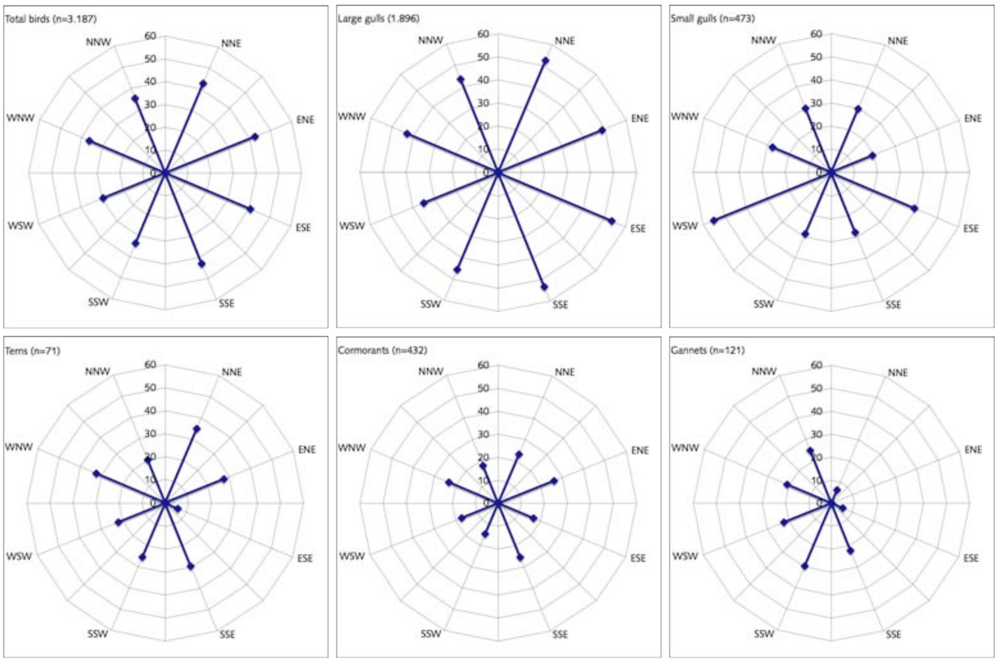

Figure 6.1 Mean flight altitudes of various species of birds, as observed during panorama scans around the metmast. Altitudes are depicted for 8 directions in the wind farm area. Longer lines reflect higher flight altitudes. The centre of the picture is the metmast, the wind farm is positioned E of the metmast., in NW-SE direction.

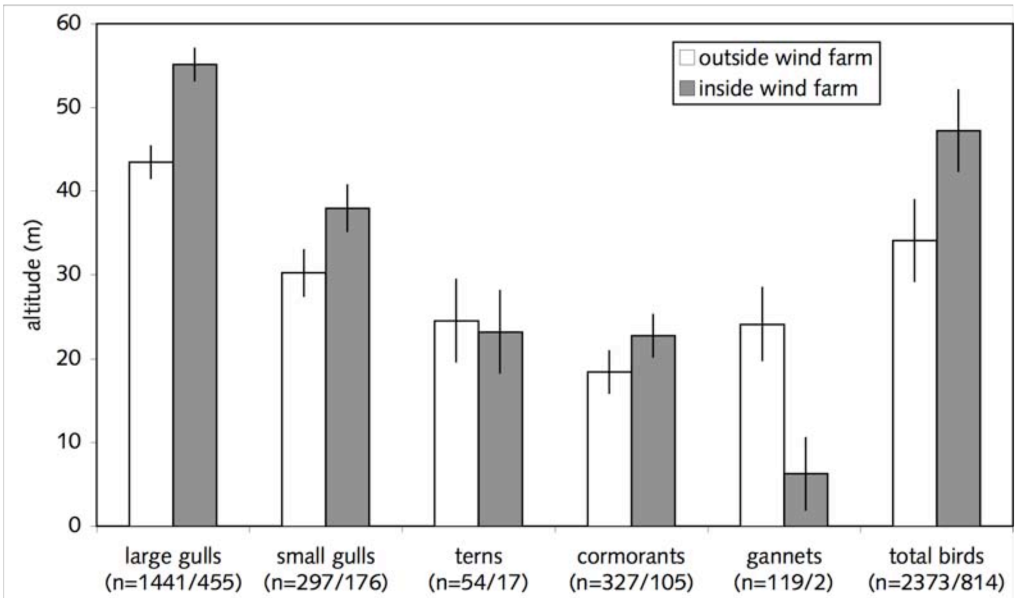

Figure 6.2 Mean flight altitude (with 95% confidence interval) inside and outside the wind farm, as observed in the panorama scans.

Paired observations in and outside the wind farm

Figure 6.3 shows the relative abundance of birds at different altitudes as observed during paired observations along transects. No overall difference in flight altitude is visible between birds flying in and outside the wind farm. Most birds were flying below rotor height, both within and outside the wind farm. In closer detail, large gulls, terns and cormorants tended to fly higher within the wind farm. For small gulls there was no clear difference and for gannets the pattern was opposite, showing lower altitudes within the wind farm (few data).

For small gulls and terns the results of the paired observations are in contrast with the results from the panorama scans. For terns this is probably due to low numbers during the panorama scans (24 birds in total). For small gulls the reason for the discrepancy is not clear.

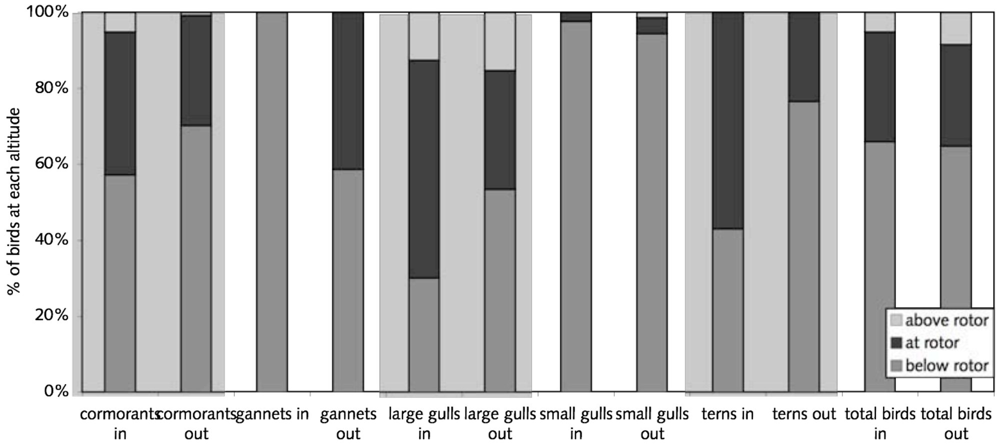

Figure 6.3 Relative abundance of birds within and outside the wind farm at different altitudes. Data are grouped per species, each group of 2 bars percentage of birds flying within and outside the wind farm. Stacked bars show percentage flying at the three altitude classes. Source: paired observations period February-October 2007.

Gannet flying between metmast and wind farm below rotor height. Photo: M. Poot

7 Discussion and conclusions

Scope of this report
In this report, results are presented on data obtained thus far on fluxes and behaviour of birds flying in the OWEZ area. The report serves as a tool to detect general patterns that are emerging from the effect study thus far. It also serves to monitor whether the research objectives are being met, whether methods that are used provide the required data or need to be adjusted.

Results and conclusions presented in the report at hand are all preliminary and may change when more data are collected during the remainder of the study period and included in the analyses. The reported study period covers less than half of the entire effect study. The majority of the data is still to be collected, and final conclusions on the effects of the wind farm can and will only be drawn after the study is completed. As a consequence, only basic results as obtained thus far are presented in this report, and not extensive analyses of the results in larger contexts, in comparison to the baseline study or to other studies. These analyses will be incorporated in the final report (2009).

Below we present the main conclusions that can be drawn from the data thus far, and briefly discuss results in the context of research objectives. First we discuss performance of the major research tool, the radar system (§7.1). Second, we discuss the three aspects of flight that are studied, i.e. fluxes (§7.2), flight paths (§7.3) and flight altitudes of birds (§7.4).

7.1 Radar performance

Conclusions
Vertical radar
- Bird movements were picked up well by Merlin: 80-90% of tracks seen visually on the Furuno screen, and in addition 10% evident bird tracks that were invisible on the Furuno screen.
- Pollution of the vertical Merlin data with clutter was substantially less than in the baseline study.
- Clutter could be removed to a large extent by filtering out those areas where clutter was most created (turbines, area 200 m around the radar).
- Additional clutter could be removed based on echo characteristics, most prominent of which was track length.
- Clutter from interference can potentially remain in the database after the current filtering rules are applied. This type of clutter originates from the metmast itself as well as from safety radars that are operational in the wind farm. Clutter analysis in the coming months will show the extent of pollution from this type of clutter and removal possibilities.
- The extent to which insects and rain pollute the database seems limited, but this needs to be evaluated in more detail using the flagged data. For this purpose, the database

on flagged (*i.e.* identified) echo tracks is extended in the remainder of the study period.

Horizontal radar

- Merlin tracked birds flying in the area when seas were calm. With increasing wave height, length of bird tracks decreased, and percentage of bird versus clutter tracks in the database decreased.
- The percentage of clutter in the data increased with increasing wave height and wind speed.
- A database was created in which data originating from birds and clutter was flagged, allowing analysis of echo characteristics, which will permit an analysis of differences in echo characteristics for the final report. Currently, not enough data are available for this analysis.
- A selection was made in the database of only those days with calm weather, in order to visualise flight paths of birds rather than sea clutter
- Days were selected for analysis on which visual observations were carried out as well, to be able to validate the horizontal data obtained through Merlin

Discussion

The **vertical radar system** performed well. The technical problems that were encountered in the baseline study were resolved, mainly as a result of the possibility to remotely shut down the radar during periods with strong winds. As a result, the vertical radar has been operating almost continuously after installation and setup was completed. The calibration tests that were carried out, all indicated that Merlin tracked most bird movements through the radar beam. Data reflect bird movements as predicted, considering fluxes that were measured through the day and over the season. Hence we can be confident that measurements on fluxes and flight altitude reflect actual bird patterns in the wind farm area.

The **horizontal radar system** performed less well, because on windy days clutter was often tracked in large quantities and on those days obscured data on flight paths of birds. The number of records on sea clutter created on those days, resulted in a bulky database that hampered data processing and analysis. As a solution, only data collected on calm days without clutter have thus far been analysed. This implies that recorded data reflect flight paths on calm days, which may deviate substantially from those of more windy days. Birds may for example fly lower when winds are stronger, and may respond to the wind farm with more deflection from the wind farm. The effects of weather conditions can be studied to some extent in the simultaneous study on local birds (Leopold & Camphuysen 2008). The ship surveys that are used to count local birds can continue up to stronger winds than either the visual observations or (possibly) the horizontal radar data analysis.

At the onset of the project, to optimise the bird/clutter ratio, Merlin settings were set to limit the amount of clutter recorded. At the end of the reported study period, in October 2007, settings were improved to record longer flight paths of birds. This has resulted in significantly improved tracking of birds, but increased the amount of recorded clutter as well.

As a result, flight paths emerged strongly from the database on calmer days. On more windy days with higher waves, the data became obscured by clutter. Data are thus useful to a limited extent. In the coming months, data processing and analysis will yield additional data on flight paths. Part of this analysis will consist of determining at what level clutter is low enough for flight paths to be accurately visualised and analysed. In addition, the dataset on flagged (*i.e.* identified) data will be enlarged and analysed, which will be a useful tool in removing clutter from the database.

7.2 Fluxes

Conclusions

Overall fluxes from vertical radar

- The vertical radar has collected data from March through the end of the reported study period in October 2007.
- Peak MTRs measured in autumn were as high as 3400 bird groups/km/h, which approaches rates measured on land.
- Compared to fluxes found during the baseline study (Krijgsveld *et al.* 2005) fluxes were relatively low in general. Especially fluxes during spring migration in April were low but this is probably due to low operational time and Merlin setting changes. More data for spring are expected during spring 2008.
- In summer, flight activity was relatively low. Nocturnal flight activity was especially, but not absent, probably reflecting gulls. In autumn, highest MTRs were recorded in the early night.

Species-specific patterns

- Visual observations showed an overall lower bird density within the wind farm than outside it.
- 75% of all birds seen in the panorama scans, were flying outside the wind farm area. Paired counts of birds along a transect line did not show marked differences in numbers inside and outside the wind farm. The reason for this discrepancy is not clear, however, numbers of birds counted in the paired observations are low.
- large gull species and gannets showed the largest differences in flight activity inside versus outside the wind farm.

Discussion

Compared to the baseline study, the current study thus far has yielded complete and good-quality data. In the baseline study, the data set on fluxes (as well as flight altitudes) was very limited because the vertical radar frequently broke down during gale force winds.

A limitation to the measurements is the range (1500m) over which data are collected. This range does cover the relevant altitudes at which birds fly over the wind farm. However, this also means that only flight patterns directly adjacent to the wind farm are measured, covering the area between turbines number 5 and 10. Hence the collected data only reflect fluxes and flight altitudes in the affected area. Fluxes and flight altitudes in a control situation without turbines are not being measured simultaneously. Data from the baseline study will be used to fill in this information, but was recorded at a different site in a different year.

To assess what species pass the wind farm area by night during the migratory period, visual observations during the night are essential. Currently, such observations are limited to a single night in October. More nocturnal observations are planned for the spring and autumn migration periods of 2008.

7.3 Flight paths

Conclusions

Flight paths from horizontal radar observations

- Data from calm days throughout the year thus far are the only data that have been used to show flight paths of birds on a larger scale in the wind farm area
- Data from autumn migration indicate that deflection occurs around the wind farm
- Analysis of daily patterns may elucidate whether flight directions in the wind farm area originate from gull movements or still also reflect clutter

Flight paths from visual observations

- Bird activity was generally low in the wind farm area, and few species were seen in comparison to the baseline study
- Gulls were the most abundant species group present in the wind farm area. Although results thus far show some variation, gulls showed no signs of avoidance of the wind farm in most observations
- Cormorants similarly showed no avoidance of the wind farm
- Gannets clearly avoided flying through the wind farm

Discussion

Flight paths thus far could be followed to a limited extent with the horizontal radar system (see §7.1). The solution to limit horizontal radar data analysis to calm days has indeed resulted in informative data on flight paths of birds in the wind farm area, which has been a significant step forward. Further analysis of the database, including more data from days with calmer weather as well as more detailed analysis of observed patterns, will yield information on deflection, which is an important aspect of this study.

A limitation to the measurements lies in the fact that the horizontal radar is limited to record data up to a maximum of 6 km from the metmast (less for the smaller songbirds). As a result, flight paths directly adjacent to the wind farm are visualised, but deflection at larger distances remains unknown. In addition, hardly any tracks are recorded in the area north to east and south of the wind farm, due to the large distance that has to be covered as well as the blind sector behind (S of) the metmast. In autumn, this seriously limits the registration of flight paths of birds coming from NE and E. During spring migration, the position of the metmast with the radars does provide a good position to detect flight paths of birds coming from SW and W.

Visual observations have proven to be of great importance in determining behavioural responses of birds to the wind farm. They have resulted in both general flight paths of birds in relation to the wind farm, as well as species-specific differences in behaviour. Because the abundance of birds in the wind farm area has generally been low, relatively many hours of observation are needed to obtain sufficient amounts of data for analysis of flight paths. Data obtained in the simultaneous study on local birds in the wind farm area (Leopold & Camphuysen 2008), will provide insight in distribution patterns of the various bird species in a larger area around the wind farm. Presence and absence of flight activity can thus be further interpreted (final report 2009).

7.4 Flight altitudes

Conclusions

Altitude distributions from radar data

- Flight altitude patterns were generally in line with results found in the baseline study (Krijgsveld *et al.* 2005). Flight activity was highest during autumn and in the night at high altitudes. In summer most activity was found at lower altitudes.
- In summer most flight activity took place at turbine height, but numbers were much lower compared to autumn. In autumn high fluxes occurred at turbine height both day and night but particularly at night in the OWEZ wind farm area.

Species-specific flight altitudes

- Data on species-specific flight altitudes were limited.
- Generally, birds seemed to fly higher inside the wind farm than outside of it.
- The few gannets that flew within the wind farm, had a lower flight altitude inside the wind farm.

Discussion

Methods used and data obtained thus far on flight altitudes are proving useful in determining flight altitudes. Data will, as expected, provide information on flight altitudes over the wind farm area. Data will be limited however to the actual site of the wind farm, and will not cover areas where birds are unaffected by the wind farm. Thus, no difference with undisturbed areas can be analysed other than as measured in the baseline situation. A point of some concern is the extent to which clutter from rain and/or insects pollute the database. This will be analysed in more detail using the growing dataset on flagged (*i.e.* identified) echo characteristics and included in the final analyses.

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9 Literature

Brasseur, S.M.J.M., P.J.H. Reijnders, O.D. Henriksen, J. Carstensen, J. Tougaard, J. Teilmann, M.F. Leopold, C. Camphuysen & J.C.D. Gordon, 2004. Baseline data on the harbour porpoise, Phocoena phocoena, in relation to the intended wind farm site NSW, in the Netherlands. Alterra-rapport 1043, ISSN 1566-7197. Alterra, Wageningen.

Camphuysen, C.J. & J. van Dijk, 1983. Zee- en kustvogels langs de Nederlandse kust, 1974-79. Limosa(56): 81-230.

Camphuysen, C.J. & S. Garthe, 2001. Recording foraging seabirds at sea: standardised recording and coding of foraging behaviour and multi-species foraging associations. NIOZ internal report, Texel, Netherlands.

Dirksen, S., R.H. Witte & M.F. Leopold, 2005. Nocturnal movements and flight altitudes of common scoters *Melanitta nigra*. Research north of Ameland and Terschelling, February 2004. Rapport 05-062. Bureau Waardenburg bv, Culemborg.

Krijgsveld, K.L., S. Dirksen & M.J.M. Poot, 2006. Effect studies Offshore Wind Egmond aan Zee: strategy of approach for flying birds. Bureau Waardenburg bv, Culemborg.

Krijgsveld, K.L., R. Lensink, H. Schekkerman, P. Wiersma, M.J.M. Poot, E.H.W.G. Meesters & S. Dirksen, 2005. Baseline studies North Sea wind farms: fluxes, flight paths and altitudes of flying birds 2003 - 2004. Bureau Waardenburg bv, Culemborg.

Krijgsveld, K.L., S.M.J. van Lieshout, H. Schekkerman, R. Lensink & S. Dirksen, 2003. Effects of a near shore wind farm on birds. Experimental design of the observations in the reference situation. Rapport 03-043. Bureau Waardenburg bv, Culemborg.

Lensink, R., M.J.M. Poot, S. Dirksen & J. van der Winden, 1998. Kwantificering van vogelbewegingen op en rond vliegveld Eindhoven; ontwikkeling van methodieken en waarneemprotocollen. Rapport 98.32. Bureau Waardenburg bv, Culemborg.

Lensink, R., M.J.M. Poot, I. Tulp, A. de Hoon & S. Dirksen, 2000. Vliegende vogels op en rond vliegveld Eindhoven. Een studie naar aantallen en dichtheden in de onderste luchtlaag. Rapport 00-005. Bureau Waardenburg bv, Culemborg.

Leopold, M.F. C.J. Camphuysen. 2008. Local birds in and around the Offshore Wind Park Egmond aan Zee (OWEZ) (T1). NoordZeeWind Rapport OWEZ_R_221_t1_20080201 Draft. Wageningen Imares, Texel.

Leopold, M.F., C.J. Camphuysen, C.J.F. ter Braak, E.M. Dijkman, K. Kersting & S.M.J. van Lieshout, 2004a. Baseline studies North Sea Wind Farms: Lot 5 Marine Birds in and around the future sites Nearshore Windfarm (NSW) an Q7. Alterra-rapport 1048. Alterra, Wageningen.

Leopold, M.F., C.J. Camphuysen, S.M.J. van Lieshout, C.J.F. ter Braak & E.M. Dijkman, 2004b. Baseline studies North Sea Wind Farms: Lot 5 Marine Birds in and around the future site Nearshore Windfarm (NSW). Alterra-rapport 1047. Alterra, Wageningen.

Lowery, H.G. & R.J. Newman, 1966. Continentwide Bird Migration. A continentwide view of bird migration on four nights in October. Lowery and Newman. Museum of Zoology, Louisiana State University, Baton Rouge, Louisiana.

Petersen, I.K., T.K. Christensen, J. Kahlert, M. Desholm & A.D. Fox, 2006. Final results of bird studies at the offshore wind farms at Nysted and Horns Rev, Denmark. NERI Report Commissioned bij DONG energy and Vattenfall A/S 2006. National Environmental Research Institute Ministry of the Environment-Denmark, Denemarken.

Poot, M.J.M. & R. Lensink, 2007. Vogeltrek over de Eemshaven in voorjaar 2007 in relatie tot nieuwe windturbines. Beschrijving van vogeltrek voor plaatsing. Rapport 07-103. Bureau Waardenburg bv, Culemborg.

Poot, M.J.M., R. Lensink, J. van Belle & H. van Gasteren, 2000. Validatie visuele waarneemmethoden met behulp van radar op de Pier van IJmuiden 1999 en vogeldichtheden boven de Pier van IJmuiden, in het kader van ONL - Vliegveiligheid en vogels. Rapport 00-083. Bureau Waardenburg bv, Culemborg.

Schweizerische Vogelwarte, 1996. Instructions to count nocturnal bird migration by watching the full moon. leaflet, Sempach, Zwitserland.

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Appendix to report: OWEZ_R_231_T1_20080304

To whom it may concern
Within the framework of the Off shore Wind farm Egmond aan Zee project, on the order of Dutch Government and with their financial support, an extensive environmental monitoring program is carried out. Research area's are birds, marine mammals, fish, benthos, solid substrate and public opinion.
The report at hand is written within the framework of the monitoring program and reports the work done in 2007 on one of the research topics. Before publication, the reports were reviewed by Dutch energy agency SenterNovem and the Waterdienst, a department of the Dutch water authority Rijkswaterstaat. The questions raised and comments of the researchers can be found in this appendix, however the text is available only in Dutch.

Aan de lezer van dit rapport

In het kader van het project Off shore Windpark Egmond aan Zee wordt, in opdracht van en met financiële ondersteuning van de Nederlandse rijksoverheid, een milieu monitoring programma uitgevoerd. Onderwerpen van onderzoek zijn vogels, zeezoogdieren, vis, benthos, hard substraat en publieke opinie.
Het rapport dat voor u ligt is gemaakt in het kader van dat programma en doet verslag van het werk dat in 2007 aan één van deze onderwerpen is uitgevoerd. Voorafgaand aan publicatie is dit concept rapport voorgelegd aan SenterNovem en de Waterdienst van Rijkswaterstaat die namens de overheid het monitoringprogramma begeleiden. Hun vragen bij dit rapport en de reactie van de onderzoekers treft u aan in deze bijlage bij het rapport.

Vragen en opmerkingen van de overheid op dit rapport:
Als progress report ligt de nadruk sterk op methodiek en calibratie. Vanwege de beperkte aantallen observaties zijn de resultaatbesprekingen compact. De studie is uitgevoerd met één van de op dit moment beste beschikbare COST systeem: beter gedefinieerde, commercieel beschikbare systemen met (primitieve) soortherkenning, o.a. door TNO (Borst 2007) en de Vogelwarte Sempach , Zwitserland (Hill & Hüppop 2007) zijn in ontwikkeling.
De voorgestelde combinatie van meetsystemen (radar+ visueel + auditief) is zeer nuttig maar de integratie ervan komt niet aan bod in dit rapport.

Een groot deel van het rapport behandelt de calibratie van de radarmetingen. Deze calibratie behelst voornamelijk een controle van de vogelherkenningsalgoritmes van de Merlin software. Dit is zeer nuttig, en ook netjes opgezet, maar daarmee is het nog geen absolute maat voor vogelaantallen. Zo'n absolute maat is nodig om verschillende locaties en situaties onderling te kunnen vergelijken, zeker als ze met verschillend meetsystemen bemonsterd zijn. Dit levert een paar cruciale vragen op:
1- Hoeveel vogels bevat één vogelecho? Voor 's nachts trekkende zangvogels is de algemene consensus, gebaseerd op waarnemingen met doelvolgradars, dat ze individueel vliegen, maar voor overige vogels zijn zulke gegevens minder eenduidig. En voor overdag vliegende vogels is de consensus juist dat groepsgrootte soortafhankelijk is en bovendien sterk bepaald wordt door weersomstandigheden.
2 – Wat zijn de dimensies van de radarbundel? Tot op welke afstand kunnen vogels worden waargenomen en hoe breed is de radarbundel? Deze informatie is noodzakelijk om echopassages
te kunnen vertalen naar migration traffic rates (MTR's), zie daarvoor oa Van Gasteren et al (2001).

Bij de calibratie van de verticale radar lijkt de datafiltering op basis van echokwaliteiten veelbelovend. Wel valt het grote contrast tussen specificiteit (99%) en sensitiviteit (51%) van de software op: een verklaring hiervoor is helaas niet gegeven. In dit licht is het opvallend dat mogelijke detectie van insecten in dit rapport nauwelijks wordt behandeld, terwijl dit algemeen geldt als een belangrijk probleem bij X-band radar (oa Schmaljohann 2007).
Bij de horizontale radar lijkt zeeclutter beperkend te zijn voor het aantal betrouwbare waarnemingen. Dit werpt de vraag op in hoeverre zeeclutter ook de ondergrens van de metingen beïnvloedt bij de verticale radar.

Op basis van de verticaal ronddraaiende radar zijn MTR's bepaald. Uit het rapport kan niet worden opgemaakt of voor daarbij vliegrichtingen en snelheden is gecorrigeerd. Dat is relevant omdat daarmee ook niet duidelijk is welk percentage van de vogels daadwerkelijk langsvliegende vogels betrof: voor lokaal rondvliegende vogels is een fluxmeting zoals die hier is uitgevoerd
Review Krijgsveld et al 2008 progress report on fluxes and behaviour of flying birds
principieel ongeschikt.
Over het algemeen komen de gemeten MTR's en dag- en seizoenspatroon overeen met waarden in andere studies. Daarbij moet wel worden opgemerkt dat, door de beperkte tijdspanne, nog slechts een klein deel van het vogeltrekseizoen is gemeten. Ook is het maximale hoogtebereik van de radar duidelijk kleiner dan de maximale te verwachten vlieghoogte bij vogeltrek. Aangezien de variatie in aantallen en vlieghoogtes van vogeltrek tussen jaren aanzienlijk kan zijn verdient het aanbeveling de metingen niet ook te vergelijken met gelijktijdige metingen van andere bronnen en de metingen over meerdere jaren te laten lopen. Voor de aantalsverdeling in de laagste klasse is onduidelijk of de werkelijke ondergrens van de verticale radar werkelijk op zeeniveau ligt of, als gevolg van zeeclutter, structureel daarboven.

De gegevens over soortverdeling zijn uitsluitend gebaseerd op visuele waarnemingen. Daarbij lijken mariene soorten, die het windpark en de omgeving gebruiken als foerageerhabitat, te domineren. Doortrekkende vogels zijn slechts incidenteel waargenomen en nachtelijke gegevens zijn nog helemaal niet beschikbaar. De vraag is in hoeverre de visueel waargenomen vogels overeenkomen met de door radar waargenomen vogels. Resultaten over vliegsporen zijn gebaseerd op radar- en visuele waarnemingen. De verschillen tussen soorten, die blijken uit de visuele waarnemingen, en de aantallen die beschikbaar komen uit de radarwaarnemingen onderstrepen het belang van de gecombineerde metingen. Die integratie is hier verder niet aan bod gekomen.

In het rapport worden aantallen en gedragingen met meerdere meetsystemen bestudeerd. Een betere integratie van deze metingen zou een belangrijke stap zijn op weg naar absolute vogelgegevens uit radarwaarnemingen. Die absolute aantallen zijn noodzakelijk om de vergelijking mogelijk te maken met andere locaties, die eventueel met weer andere meetsystemen worden bemonsterd.
Een andere stap die binnen dit rapport onvoldoende aan bod komt betreft de dimensies van de radarbundel en de onzekerheden die die met zich meebrengen.

<u>Reactie van de onderzoekers:</u>
Genoemd wordt dat gewerkt wordt met “één van de op dit moment beste beschikbare COST systemen”. In dit verband is relevant te melden dat de keuze voor het systeem al in 2005 gemaakt moest worden, en het systeem toen het best beschikbare en tevens betaalbare systeem was dat radargegevens digitaal kon verwerken.
Er is expliciet voor gekozen de integratie van radar –, visuele – en auditieve methodes niet in het tussenrapport aan bod te laten komen. Enerzijds omdat het een tussentijdse presentatie van gegevens betreft, en integratie van zeer voorlopige en beperkte resultaten een zekerheid van de resultaten suggereert die zeker in januari 2008 nog niet gegeven kon worden. Anderzijds worden de systemen wel onderling vergeleken vanuit een calibratie-oogpunt. Beide aspecten krijgen in het tweede tussenrapport, dat verschijnt in 2009, aanzienlijk meer aandacht. In het eindrapport dat verschijnt in het voorjaar van 2010 worden de resultaten van de diverse methodes geïntegreerd.

Het radarsysteem kan het aantal vogels per echo niet onderscheiden. Hoewel dit de meting inderdaad minder absoluut maakt, geven de resultaten genoeg inzicht in de fluxen om de onderzoeksvraag te kunnen beantwoorden, namelijk bepalen van aantallen slachtoffers middels combinatie van flux en aanvaringskans, en inschatten van cumulatieve effecten van aanvaringen op populatieniveau.
Dimensies van de radarbundel kunnen worden berekend op basis van radarspecificaties en –instellingen. Dit zal in het eindrapport worden gedaan. De range van de verticale radar (0.75NM) is zo gekozen dat detectie van soorten (hoe kleiner de range hoe meer soorten gedetecteerd) en bereik c.q. hoogte (hoe groter de range hoe groter het bereik) zijn geoptimaliseerd.
Insecten worden nauwelijks geregistreerd door het Merlin systeem en vormen daarmee geen probleem. Dit wordt behandeld in het tweede tussenrapport op basis van de uitgebreidere data-set.
Zeeclutter wordt in de verticale radar slechts tot werkelijke golfhoogte geregistreerd. Alleen vogels in de onderste 2-3 m boven zeeniveau vallen daarmee weg. Dit betreft met name laagvliegende soorten zeevogels, waarvoor aantallen en gedrag vooral op basis van visuele waarnemingen worden bepaald i.v.m. de lage dichtheid. Dit wordt besproken in het tweede tussenrapport.

Aantallen en verspreiding van lokale vogels worden behandeld in het betreffende onderzoek (Leopold & Camphuysen 2008); vliegbewegingen en uitwijkgedrag van deze groep is voorzover op dat moment bekend besproken in het hoofdstuk over vliegpaden, en in meer detail komt dit aan de orde in de tweede tussenrapportage en het eindrapport.

Naarmate er meer resultaten beschikbaar komen, wordt een verdere integratie gemaakt. Dit komt aan de orde in het tweede tussenrapport en met name in het eindrapport.

Een zo nauwkeurig mogelijke bepaling van aantallen wordt nagestreefd, maar absolute aantallen zijn niet noodzakelijk om effecten van OWEZ te kunnen bepalen dan wel om vergelijkingen van vogelaantallen bij andere windparken te kunnen maken. Gezien de grote variatie in aantallen en soortsamenstelling op basis van bijvoorbeeld weersomstandigheden moet immers een betrouwbaarheidsmarge gehanteerd worden in de berekening.