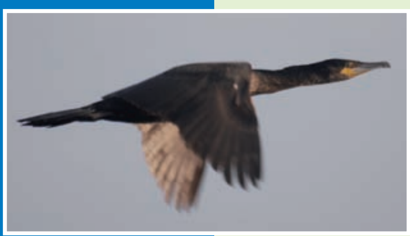
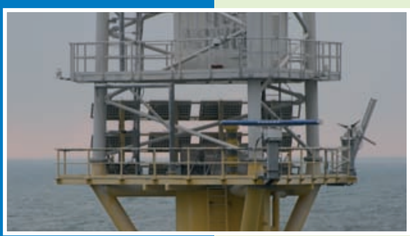
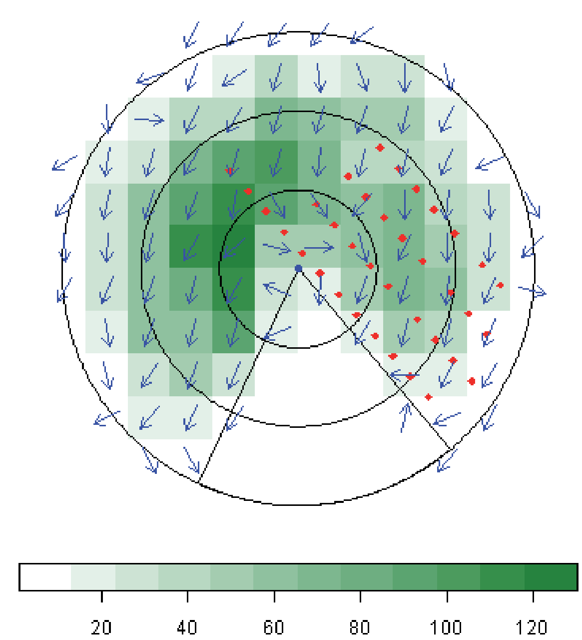
Effect studies Offshore Wind Farm Egmond aan Zee

Progress report on fluxes and behaviour of flying birds covering 2007 & 2008







K.L. Krijgsveld
R.C. Fijn
C. Heunks
P.W. van Horssen
J. de Fouw
M. Collier
M.J.M. Poot
D. Beuker
S. Dirksen

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NoordzeeWind

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D. Beuker
S. Dirksen

Bureau Waardenburg bv
Consultants for environment & ecology
P.O. Box 365, 4100 AJ Culemborg The Netherlands
Tel. +31 345 51 27 10, Fax +31 345 51 98 49
E-mail wbb@buwa.nl Website: www.buwa.nl

commissioned by: Noordzeewind

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cormorant by Daniel Beuker
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Bureau Waardenburg bv
Consultants for environment & ecology

P.O. Box 365, 4100 AJ Culemborg The Netherlands
Tel. +31 345 51 27 10, Fax +31 345 51 98 49

E-mail wbb@buwa.nl Website: www.buwa.nl

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 is 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, describing the reference situation before construction of the wind farm, has been carried out in 2003-2005 (Dirksen *et al.* 2005; Krijgsveld *et al.* 2005). The study design of the effect study is presented in the strategy of approach (Krijgsveld *et al.* 2006), including the general set up of the study and the techniques that are employed. In March 2008 preliminary results obtained in 2007 were reported (Krijgsveld *et al.* 2008).

The report at hand is a status report presenting preliminary results on flying birds, collected from the start of the program in the spring of 2007 until the end of 2008. Data are based on both radar and visual observations, carried out in the wind farm area. In the final report, planned in 2010, results of the entire monitoring program will be analysed and presented in further detail.

The Offshore Wind farm Egmond aan Zee has a subsidy of the Ministry of Economic Affairs under the CO2 Reduction Scheme of the Netherlands.

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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 economical and social related, as well as benefits gained 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 the summer of 2006 the OWEZ wind farm was built by order of NoordZeeWind (Nuon Duurzame Energie and Shell Wind Energy) and the site is in operation since January 2007. It consists of 36 turbines positioned 10-18 km off the coast of Egmond aan Zee in the Netherlands.

Monitoring and Evaluation Program

The wind farm 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.

This report

The report at hand is the second interim report of the effect study. It gives a summary of the results obtained thus far, from the start of the project in March 2007 until December 2008. The report shows the status of results on species composition, fluxes, flight paths and flight altitudes. See chapter 3 for a process description of the monitoring program. The purpose of this interim report is to provide an overview of the results that have been obtained thus far. It is not meant to provide an analysis of the results, nor is it meant to give an exhaustive description of methods and limitations thereof, nor is it meant to present conclusions.

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:

1. collisions of flying birds with turbines or their wake;
2. disturbance of flight paths, so-called barrier effects;
3. disturbance of locally resting and/or feeding birds.

The study at hand focuses on effects on flying birds, and covers the first two aspects. It includes measurements of the distance from the wind farm at which various species groups show deflection. A related study carried out by Imares and Bureau Waardenburg focuses on occurrence and distribution of local birds, and covers the third aspect. For information on this subject we refer to the interim reports of 2008 and 2009 by Leopold and co-authors.

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 because 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 to 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 of landbirds mainly takes place during the night, when the risk of collision is thought to be increased due to lower visibility (Witte & van Lieshout 2003).

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?

1.3 Outline of chapters

The outline of chapters in this report is as follows.

- Chapter 2. Description of materials and methods.
- Chapter 3. Process description, including the time frame in which the various aspects of this study are carried out, and an overview of the reports written thus far and to be written
- Chapters 4-6. Overview of the results obtained thus far.
  -chapter 4: results on fluxes, or flight intensities, of birds in the wind farm area,
  -chapter 5: results on flight paths,
  -chapter 6: results on flight altitudes.
- Chapter 7. Discussion of results.

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 bird calls are being carried out from the metmast in the OWEZ wind farm area. Methodological information can be found in the following paragraphs:

- §2.1: location of the wind farm and position of turbines and metmast,
- §2.2: overview of the days on which visual observations were carried out, along with the weather conditions,
- §2.3: visual observation methods. These include panorama scans and following flight paths of individual birds,
- §2.4: radar observation methods. These include a vertically and a horizontally turning radar, that collect data continuously through an automated detection system called Merlin, which was developed and supplied by DeTect Inc. (Florida, USA).

2.1 Study area

The OWEZ wind farm is positioned between 10 and 18 km off the Dutch coast near Egmond aan Zee (fig. 2.1). It consists of 36 Vestas V90 turbines. The total area covered by the wind farm is c. 27 km^2. The distance between the turbines is relatively large with c. 650 m within rows and c. 1000 m between rows. Specifications are listed in table 2.1.

Table 2.1. Some dimensions of the OWEZ turbines

capacity per turbine	3 MW
hub height	70 m*
rotor diameter	90 m
rotor altitude max	115 m*
rotor altitude min	25 m*

*above mean sea level

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

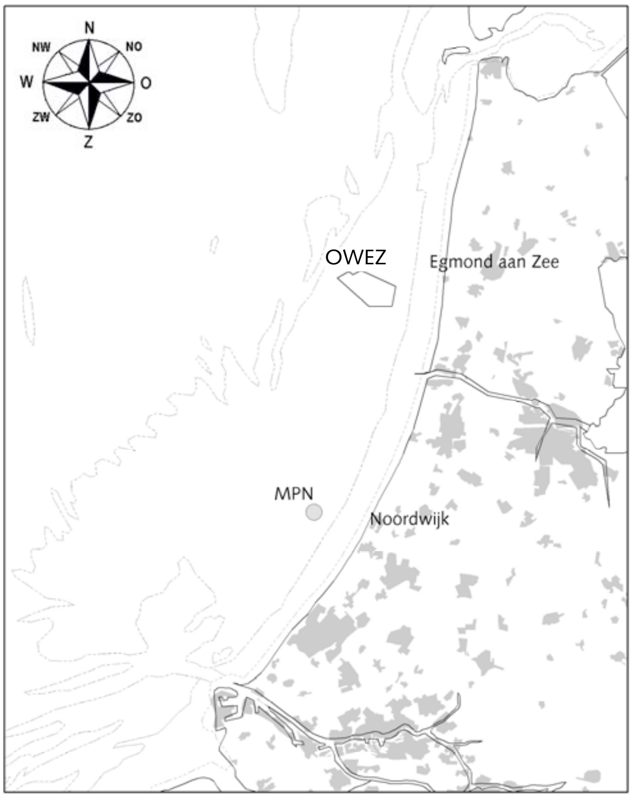


Figure 2.1 Location of the OWEZ wind farm, as well as of the observation platform 'Meetpost Noordwijk' (MPN) that was used in the baseline study.

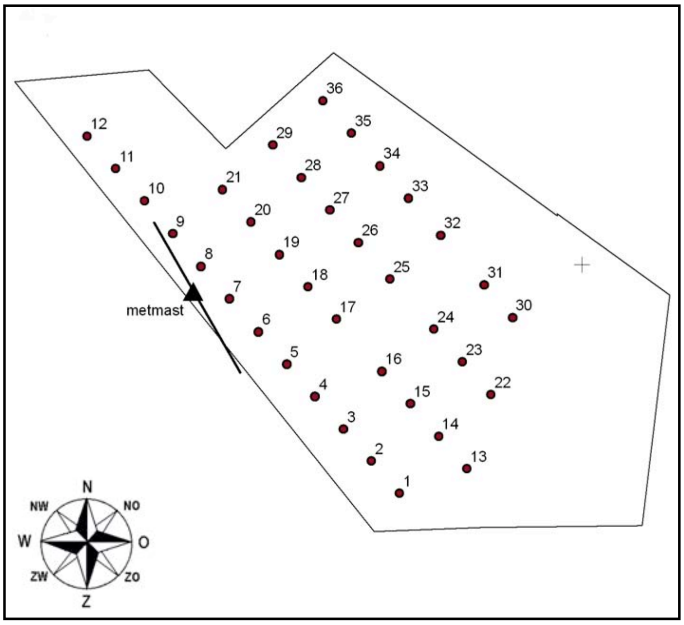


Figure 2.2 Outline of the wind farm with the position of the metmast (triangle) as well as orientation of the vertical radar beam (black line through metmast). Photograph shows the metmast from the south and two wind turbines (Photo: K. Krijgsveld).

2.2 Overview of observation days

Visual observations

The reported study period covers the start of the effect study in March 2007 until the end of December 2008. Visual observations were carried out on 32 days and 4 nights (table 2.2). Weather conditions on the observation dates are also shown in table 2.2.

Radar observations

The radars were installed on the metmast late January 2007. Initial data collection could be started on February 23 2007, at which point settings were untested. Remotely controlling the radars (switching from transmit mode to stand-by mode and *vice versa* from the BuWa-office) was first accomplished in early 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 2007 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 was recorded by Merlin.

Table 2.2 *Overview of observation days in the reported period from spring 2007 through December 2008. 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 °C	clouds/rain
Winter 2006/2007							
Feb21	start-up/installation	SSW	3-4	50-90	3	10	cloudy, rain
Spring 2007							
Mar 15	start-up/installation	SW	4	60	5	10	clear, dry
Mar 26	start-up/installation	E	4		5	10	clear, dry
Apr 5		W	3		10	12	partly cloudy, dry
Apr12		N	3	80	10	15	clear, dry
May 25		S	1	30	10	20	partly cloudy, dry
Summer 2007							
Jun 5	radar maintenance	NE	5	90			dry
Jun 21	1/2d; thunderstorm	VAR	3	50	25	18	partly cloudy, dry
Aug 2		NW	4	60	10	18	partly cloudy, dry
Aug 20		SSE-NNE	1-4		15	18	cloudy, few showers
Autumn 2007							
Sep 6		NW	4	90	10	16	cloudy, dry
Sep13		NE-SE	3-1	70	10	17	cloudy, dry
Oct 2/3 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
Winter 2007/2008							
Jan 28		SW	3	100	10-5	7	cloudy, later hazy
Feb 11		SE	2-1		25	8	sunny
Feb 19		E	2	100	0,5	5	cloudy with fog
Spring 2008							
Mar 27		NE	3	80		5	cloudy
Mar 27/28 night		NE-S-W	3-1	100-70	-	5	drizzle and overcast
Apr 4		SW	3	90	10-3	8	overcast, dry, foggy
Apr 9		S-SW	2-3	80	10	10	sunny
Apr 23/24 night		SE-SW	2-1-3	50	1	10	drizzle but clearing
Apr 24		SW	4-5	90	1	10	
May 08		E	3	60	5	13	
May 21		ENE	4	100	10	15	
Summer 2008							
June 25		NE-SW	2-4	70	50	15	sunny, some clouds
July 23		NW	2		15	20	clear, sunny
July 29		NW	3-4		2-3	20	cloudy
Aug 6		SW	3	80	10	20	cloudy, dry
Fall 2008							
Sep 11		S	3-4		5	15	cloudy
Sep 17		E	1-2	40	15	15	sunny, some clouds
Sep 17/18 night		NE	2	40		10	clear
Oct 13		WSW	3-4		5	12	Cloudy, blue patches
Oct 30		NE	3-4	90	15-8	5	clear later overcast
Nov 4		NE	1	100-80	0,2-1	8	thick fog all day
Nov 6/7 night		SE-SW	3-4		5	10	cloudy,some showers
Winter 2008/2009							
Dec 1		NE	2-3	60	3-5	5	overcast and fog
Dec 18		S	2-3	50	0,5-1,5	2	thick fog all day

2.3 Visual observation methods

2.3.1 Panorama scans

During observations, a panorama scan was carried out every hour during daylight. 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). 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. A list of bird species names in Dutch, English and Latin can be found in Appendix I. Recording was done on preprinted forms.

The panorama scan is in essence comparable to a radar scan: by slowly moving the binoculars in one direction, the observer scans the air 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.

Results of panscans 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 that should be considered separately rather than being included in the main data set on flying birds. For these reasons, locally active birds (without distinct direction) and birds sitting on the water were analysed separately. In the final report the data will be analysed in more detail (e.g., comparison with baseline study, relationship with weather conditions and with fishing vessels).

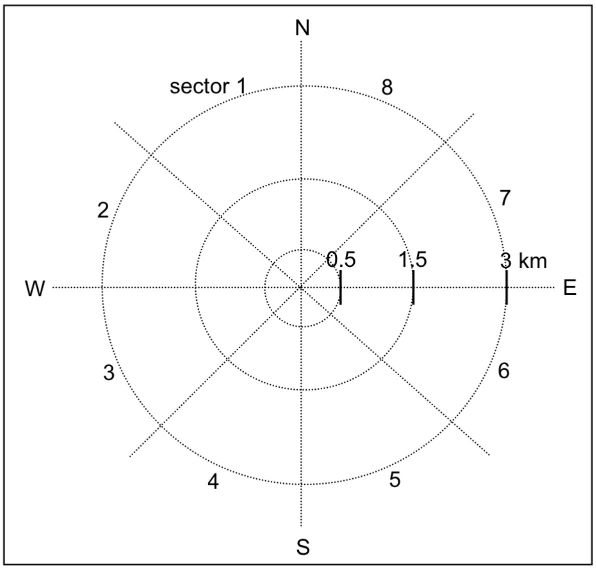


Figure 2.3 Schematic view of the panorama scans with the division in sectors and distances. The metmast, as observation platform, is situated in the centre. Surface areas are: distance 0-0,5km=0,79km^2, 0,5-1,5km=6,28 km^2, 1,5-3km=21,21km^2. For scan altitudes see fig. 2.4.

Observer carrying out a panorama scan, counting birds in sector 5 or SE. Photo: C. Heunks.

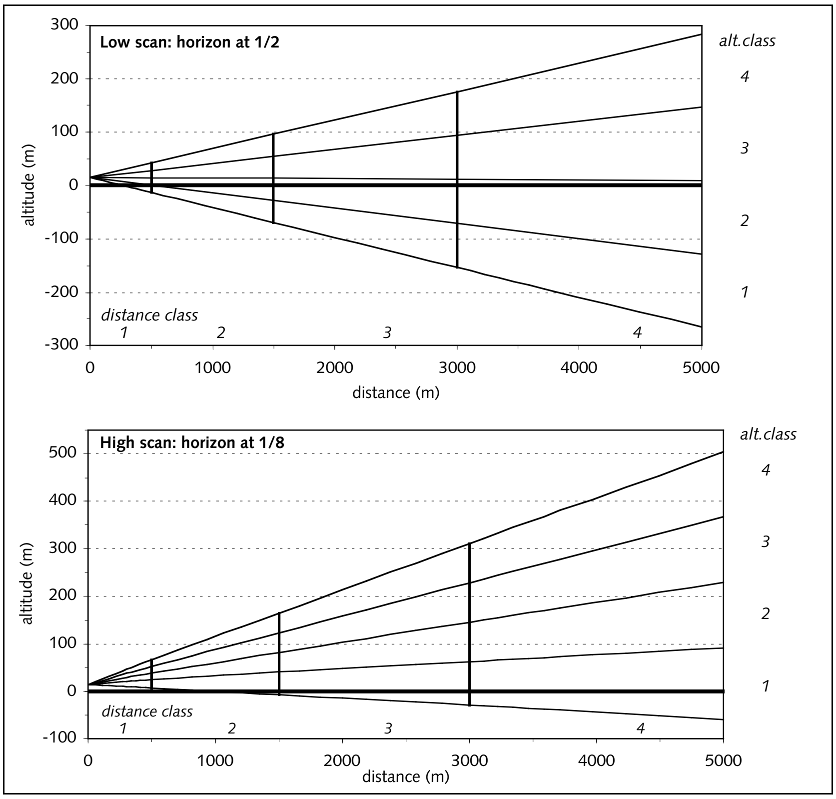


Figure 2.4 Schematic view of the volume of air covered with panorama scans. Scans were performed at two altitudes: a low scan with the horizon halfway the binocular view and a high scan with the horizon at 1/8 in the lower part of the binocular view. With the sea surface visible in the bottom part of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

2.3.3 Flight paths through the wind farm

During visual observations flight paths of individual birds or bird groups were followed as much as possible. Emphasis was laid on flight paths of birds flying through or towards 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. During migration, species composition at night is very different from that during daytime, because species have a strict preference for diurnal or nocturnal migration.

During hours of darkness, species can be identified by call identification. The range is limited and depends on the level of background noise. We estimate that birds can be heard up to a distance of c. 100 m. In addition, species identification as well as visual registration of flight paths is possible through moon watching (Lowery & Newman 1966); Schweizerische Vogelwarte, Instructions Manual 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.

Nocturnal observations were carried out on five nights (2 in spring, 3 in autumn). On these nights bird calls were registered, and birds were identified and counted by moon watching.

In addition, a system is being developed by Leiden University in cooperation with Bureau Waardenburg, with which calls can be recorded and analysed automatically. This system has been operating on the metmast during the migratory seasons in 2007, during which time it has continuously recorded birdcalls. Currently, a sound library is developed with which the recorded data can be processed to exclude background noise, and to give information on the level of bird species. Because development and analysis are in progress, results will be presented in 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 2.3.

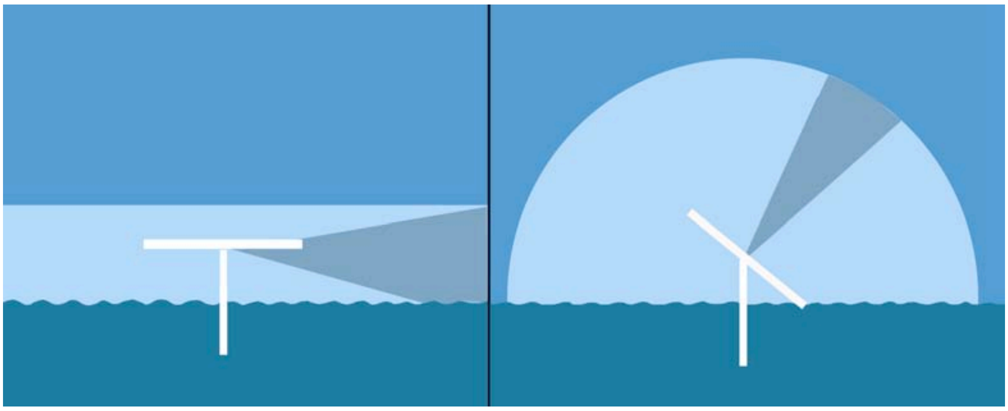


Figure 2.6 Schematic view of the horizontal (left) and vertical radar. Radar bundle is shaded in the image.

Table 2.3 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 c. 13m	axis c. 13 m above mean sea level
Merlin software	versions 3.4.44 – 4.0.6	versions 3.4.44 – 4.0.6

The radars scanned an area of up to 6 km (3 NM; horizontal radar) around and up to 1,5 km (0.75 NM; vertical radar) 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. The exact location, direction, speed, and altitude was registered of 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 is being used, a system developed and supplied by DeTect Inc. (Panama City, FL, USA). This system entails not only the radars, but also computer-radar interfaces and software. With this system the radar signal is 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 (appendix III).

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 and described in Appendix II.

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 are reduced and summarised to 1 record per track.

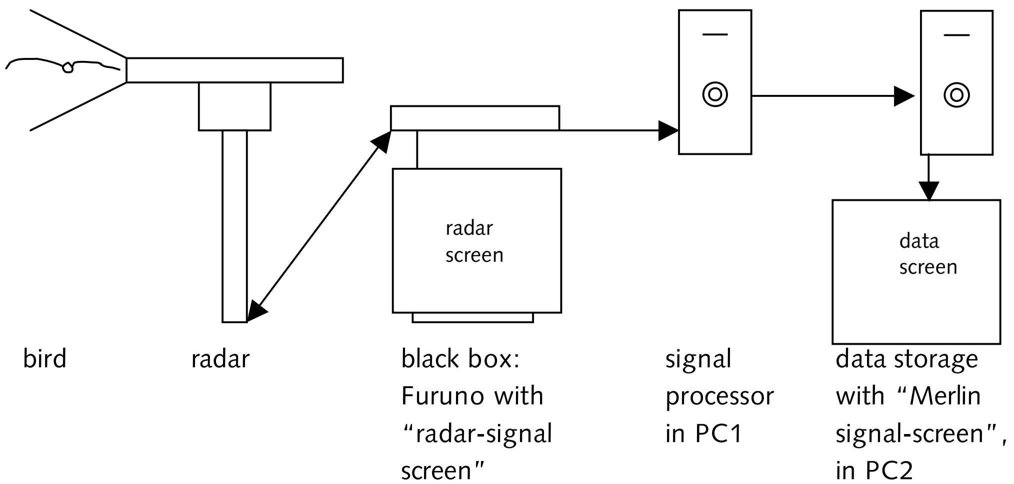


Figure 2.7 Schematic overview of the horizontal radar equipment used. The setup for the vertical radar is identical.

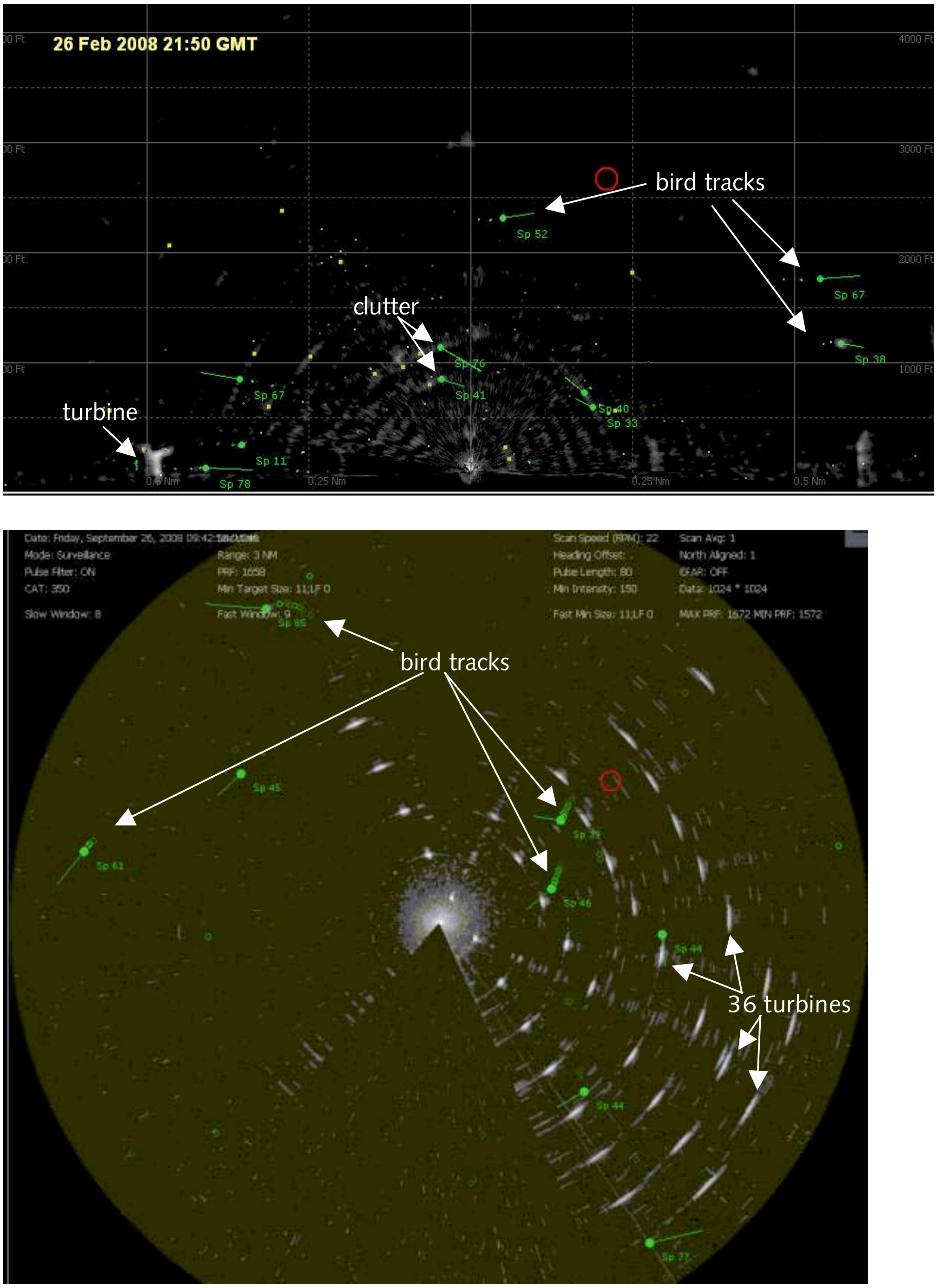


Figure 2.8 Image of the Merlin screens of vertical (top) and horizontal (bottom) radars. Solid green dots reflect recorded tracks. Flight direction is indicated by a green line Small closed (top) or open green (bootm) dots: track history; white: non-recorded signals received by the radar. Visible on the vertical screen are two turbines as well as interference around the radar (white), some recorded interference in the clutter around the radar, and several bird tracks. Visible on the horizontal screen are the metmast (center), the turbines, some clutter around the metmast (white), some bird tracks (green, top half) and some tracks of clutter (green dots, lower half).

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 31st of December 2008. In the reported period the vertical radar was not operated all the time (11,600 out of 16,056 hours; 72%) due to weather conditions and maintenance. Since October 2007 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). Some shorter interruptions occurred due to magnetron or print plate failure.

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, movement of the sea surface (waves) or interference from other radars. To be able to remove these data from the database, a series of tests and experiments was done to identify and discriminate between records from birds and clutter. This is described in appendix III. Insects were sometimes visible in summer on the Furuno screen, but were rarely tracked by Merlin. When insects were tracked, these tracks were very short and limited to the area directly above the radar. Because this area was excluded from analysis, insect tracks are excluded from analysis. Clutter from waves was limited to the lowest few meters and did not obscure tracks of birds flying at low altitudes. After removal of clutter two columns of each 470 m wide were selected for analysis (fig. 2.9).

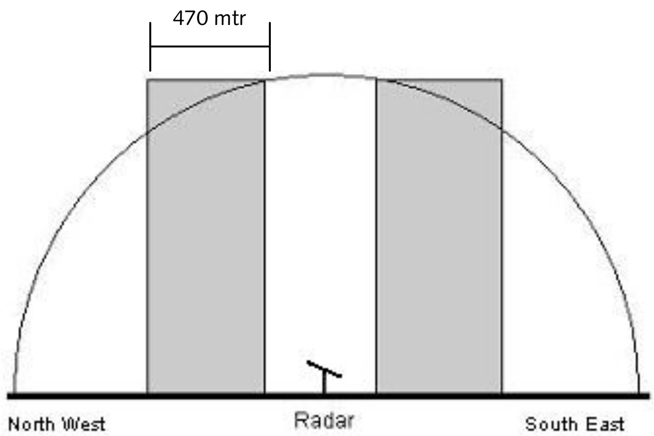


Figure 2.9 Schematic view of the two columns (grey area) in which all tracks were selected for analysis of flux and flight altitude. Columns are each 470 m wide.

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 31st of December 2008. In this period, the radar has been operational almost continuously.

Data analysis horizontal radar

Echoes from waves (sea clutter; resulting from radar energy reflected by waves) were erroneously stored in large amounts in the database, as described in app. III (see also results from the baseline study in Krijgsveld *et al.* 2005). This is a problem when using (any type of) radar at sea. To date 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 app. III.

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 the filter to remove clutter from the data base is still being developed (see app. III, data presented in final report 2010).

2.4.5 Visual monitoring and calibration of radars

Various 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 database 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 fieldwork 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 compare the tracks seen by the radar (on the Furuno screen) with those recorded by Merlin, we made digital photos from the Furuno screen at 5-minute intervals. Series of photos were made during all visits to the metmast.

The photos provide an alternative database, independent of Merlin, of flight paths in the wind farm area. Flight paths were digitised in GIS, and number of tracks and flight direction was analysed.

The digital photos were also used to compare the number of tracks seen visually versus the number recorded by Merlin within versus outside the wind farm. Tracks in a subset of 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 in 2007, 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 with a 30 second-history). By linking these data to the data recorded by Merlin at that time, they can be used to validate and calibrate the Merlin data.

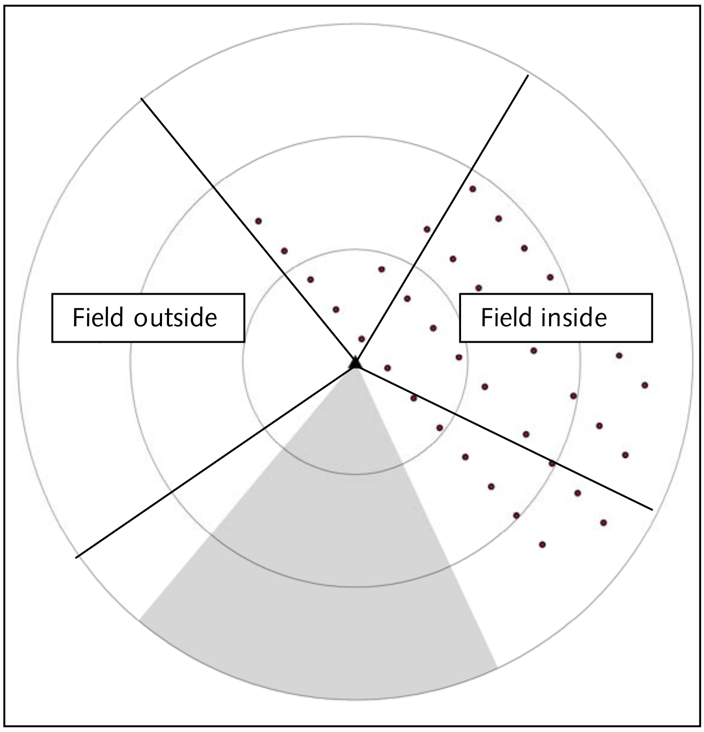


Figure 2.10 Schematic view of the two fields in which flight movements were counted.

3 Process description

In this chapter we give an overview of the monitoring program of which this report is part. The various processes involved are presented in a time frame. With this overview, the report at hand and the results presented can be placed in their proper context.

3.1 Study aims

The current study aims at obtaining data on flight patterns of birds, in order to interpret occurrence of:

1. collisions of flying birds with turbines or their wake;
2. disturbance of flight paths, so-called barrier effects;
3. disturbance of locally resting and/or feeding birds.

For this purpose we are quantifying fluxes, flight paths and flight altitudes of both local and migrating marine birds as well as non-marine migrating birds in the area. The occurrence and distribution of local birds is studied by IMARES and covers the third aspect. For further details on study aims see chapter 1.

3.2 Time frame of the study

2001-2002	An extensive Monitoring and Evaluation Program (MEP-NSW) has been designed by the Dutch government in which the economical, technical, ecological and social effects of the OWEZ are to be collected.
2003-2004	Baseline studies are carried out prior to construction of the wind farm. For the baseline studies, contracted out by the Ministry of Transport and Public works, research on birds is separated in two separate studies: one on local birds (Lot 5) and one in which flight patterns of local and migrating seabirds as well as non-marine migrating birds are being studied (Lot 6). IMARES and Bureau Waardenburg are contracted for these two studies. IMARES is responsible for Lot 5, Bureau Waardenburg is responsible for Lot 6 on flying birds.
2003-2006	Based on a proposal that is part of the tender procedure for the OWEZ concession, IMARES and Bureau Waardenburg are being contracted by Noordzeewind for the T1 phase of bird research.
2006	Strategy of approach for the effect study for flying birds is completed (Krijgsveld *et al.* 2006).
2007-2008	Effect studies Offshore Wind Egmond aan Zee are being carried out. A monitoring program runs from spring 2007 until the end of 2008 to study the effects of the wind farm on flying birds. Simultaneously, effects on local birds are studied in a related project lead by IMARES.
2009	The monitoring program is extended to obtain additional data on wintering sea birds and on spring migration, as well as to gain better insight in flight behaviour close to wind farms. These changes in the monitoring program have been discussed and implemented late 2008, and have been documented in a new strategy of approach.
2010	Presentation of the final report.

3.3 Relevant publications

Reports published before

To assess the effects of the OWEZ wind farm on flying birds, a series of studies has been carried out, that are published in related reports:

- *Baseline study 2003-2004.* Flight patterns were recorded in the 'reference situation', *i.e.* the situation without wind turbines. This baseline study was carried out in 2003-2004 and results are published in (Dirksen *et al.* 2005; Krijgsveld *et al.* 2005). Data from a closely related project on locally foraging birds and mammals in a larger area around the wind farm are published in (Brasseur *et al.* 2004; Leopold *et al.* 2004).
- *Effect study 2007, first interim report.* Effects of the wind farm on flying birds are being monitored since March 2007. A first status report was presented in January 2008 on the data collected from March through October 2007 (Krijgsveld *et al.* 2008). This report showed the first results on fluxes, flight paths and flight altitudes of birds in the OWEZ area, and discussed the influence of the OWEZ offshore wind farm on flying birds as suggested by the results at that stage.

This report

The report at hand is the second interim report of the effect study. It gives a summary of the results obtained thus far, from the start of the project in March 2007 until December 2008. The report shows results on species composition, fluxes, flight paths and flight altitudes, similar to the first interim report but extended with results obtained over 2008. Simultaneously, the second interim report on the effects on local birds is written by IMARES (Leopold *et al.* 2009). The current interim report is intended to give an overview of results obtained thus far and to present preliminary insights gained thus far on responses of birds to the wind farm in their flight behaviour. It is not intended to present final results or to present all interactions between related aspects of the study. Nor is it intended to present a full analysis of the data available thus far.

Final report

The final report of this study will be written in the first months of 2009. This final report will include all results obtained from the study and a full analysis of the data. At this time, data will be integrated and presented in further detail, and a comparison with the baseline study will be made. Results will be interpreted in the light of collision risks, barrier effects and disturbance.

4 Results on fluxes

In this chapter data are presented on the flux, or 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.* the 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.

Summary of results

Observations in 2009 confirm the pattern found in 2008 that flight activity of birds in the area generally is low. Especially activity of local birds in the area was low. During migratory periods in spring and especially autumn, flight intensities reached levels similar to those measured on land. The majority of the birds consisted of gulls. During migration periods songbirds dominated.

4.1 General patterns (from radar observations)

Seasonal variation of fluxes

Fluxes differed clearly between the various reported months. In general fluxes were low with reasonably consistent fluxes throughout spring and summer, and a peak during autumn migration (figure 4.1). In 2008 a slightly smaller peak was present in March and April during spring migration. Additional data on spring migration will be collected in the coming 2009 spring season. These data will be an important addition to data on spring migration and will yield further insights in fluxes.

The mean MTRs shown in the following graphs are averages of all the hours a bird/bird group was recorded by the vertical radar. Hours when the radar was turned off were not counted nor were hours with no flight movements. In the second graph MTRs are summed for the months, clearly showing high numbers of migratory birds recorded in October 2008. Timing of migration is more clearly visible using the summed MTR's in graphs. Disadvantage of using summed MTR's is the difference in radar effort (time the radar has been running) between the different months. Therefore also mean MTR graphs are shown.

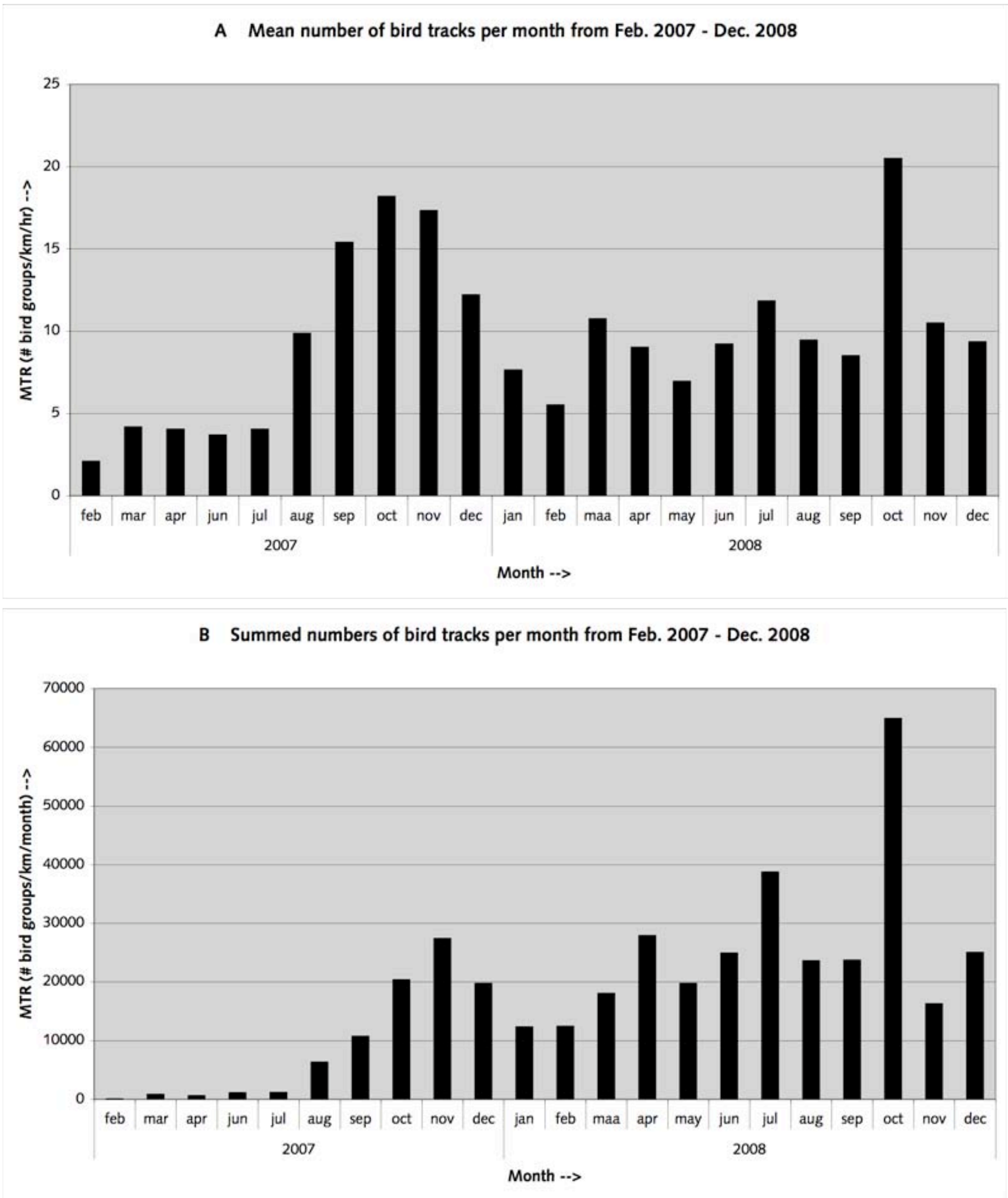
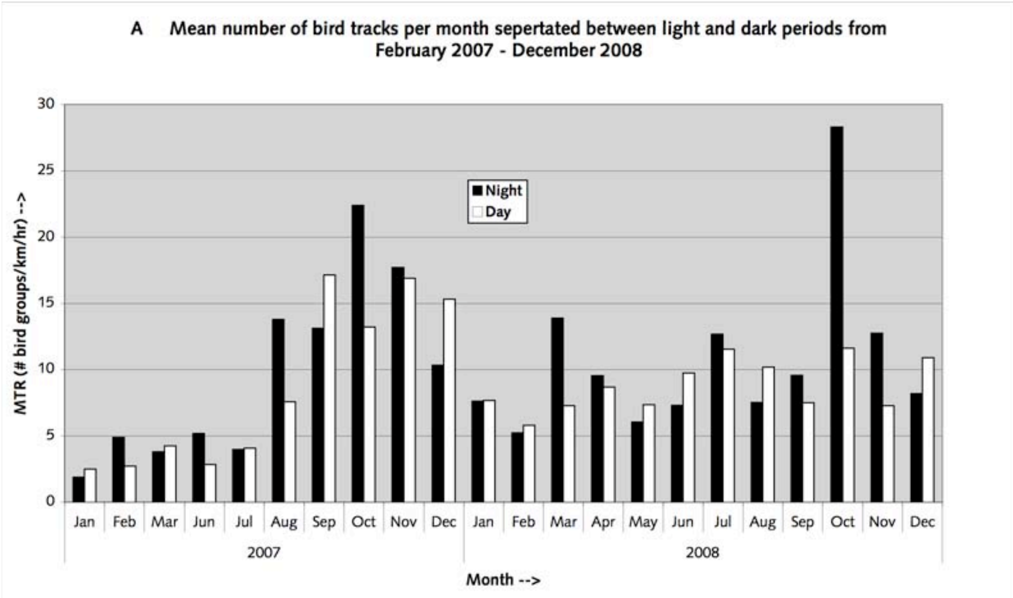


Figure 4.1 *Mean Traffic Rate for all altitudes and both day and night combined measured by vertical radar. MTRs shown are averages (A) and sums (B) for the entire month. Note the elevated MTRs around October during autumn migration.*

Fluxes during night and day

Bird migration generally reaches higher fluxes during night than 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. Differences in MTR during day and night were visible in all months (fig. 4.2). During migration differences between nocturnal and daytime MTRs seemed more pronounced than during the months with no migration. In general summer and winter months showed more flight activity during the day whereas in migration periods more night activity was found.



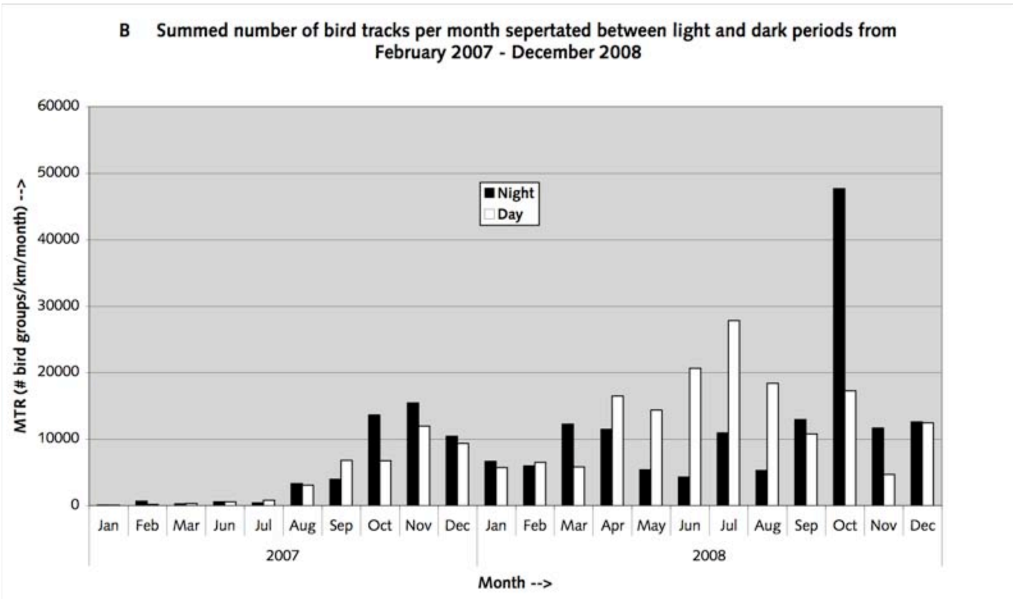


Figure 4.2 Mean Traffic Rate during day (white bars) and night (black bars). Data for all altitudes combined and averaged (A) or summed (B) over the entire month, as measured by vertical radar.

Diurnal variation in fluxes

In addition to seasonal patterns, flight activity within months also showed strong variation. Not all twenty-four hours of a specific month were 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 for each month. The highest MTR was measured in the night on the 29th of October 2008, with 2623 bird groups/hr/km. This was a night at the end of the migratory season, with south - southeasterly winds up to 4 Bft.

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

Date	Hour period	MTR (# bird groups/hr/km)
24-02-2007	16:00 - 17:00	6
08-03-2007	19:00 - 20:00	82
16-04-2007	18:00 - 19:00	52
19-06-2007	22:00 - 23:00	44
12-07-2007	12:00 - 13:00	117
22-08-2007	22:00 - 23:00	267
18-09-2007	18:00 - 19:00	423
29-10-2007	17:00 - 18:00	1113
28-11-2007	12:00 - 13:00	1163
11-12-2007	22:00 - 23:00	1150
28-01-2008	18:00 - 19:00	556
28-02-2008	17:00 - 18:00	979
28-03-2008	01:00 - 02:00	845
29-04-2008	18:00 - 19:00	989
21-05-2008	12:00 - 13:00	1260
21-06-2008	21:00 - 22:00	731
16-07-2008	21:00 - 22:00	1548
27-08-2008	17:00 - 18:00	920
07-09-2008	05:00 - 06:00	543
29-10-2008	19:00 - 20:00	2623
13-11-2008	00:00 - 01:00	644
17-12-2008	15:00 - 16:00	521

Flight intensity during the day and night showed variation in numbers of bird groups as well. For example, in late summer and autumn, high migration activity was expected to result in relatively high MTRs during the night compared to the day. In the breeding season, flight activity was expected to be limited mostly to daytime.

Autumn migration occurred especially in the beginning of the night (October). The general pattern in the other months showed slightly increased flight movements during the day and less during the night (figure 4.3 A-L). In several months two daily peaks with higher numbers of birds were found in the morning and the evening. This probably reflected movements to and from roosting sites. A similar pattern in activity through the day was found for 2007.

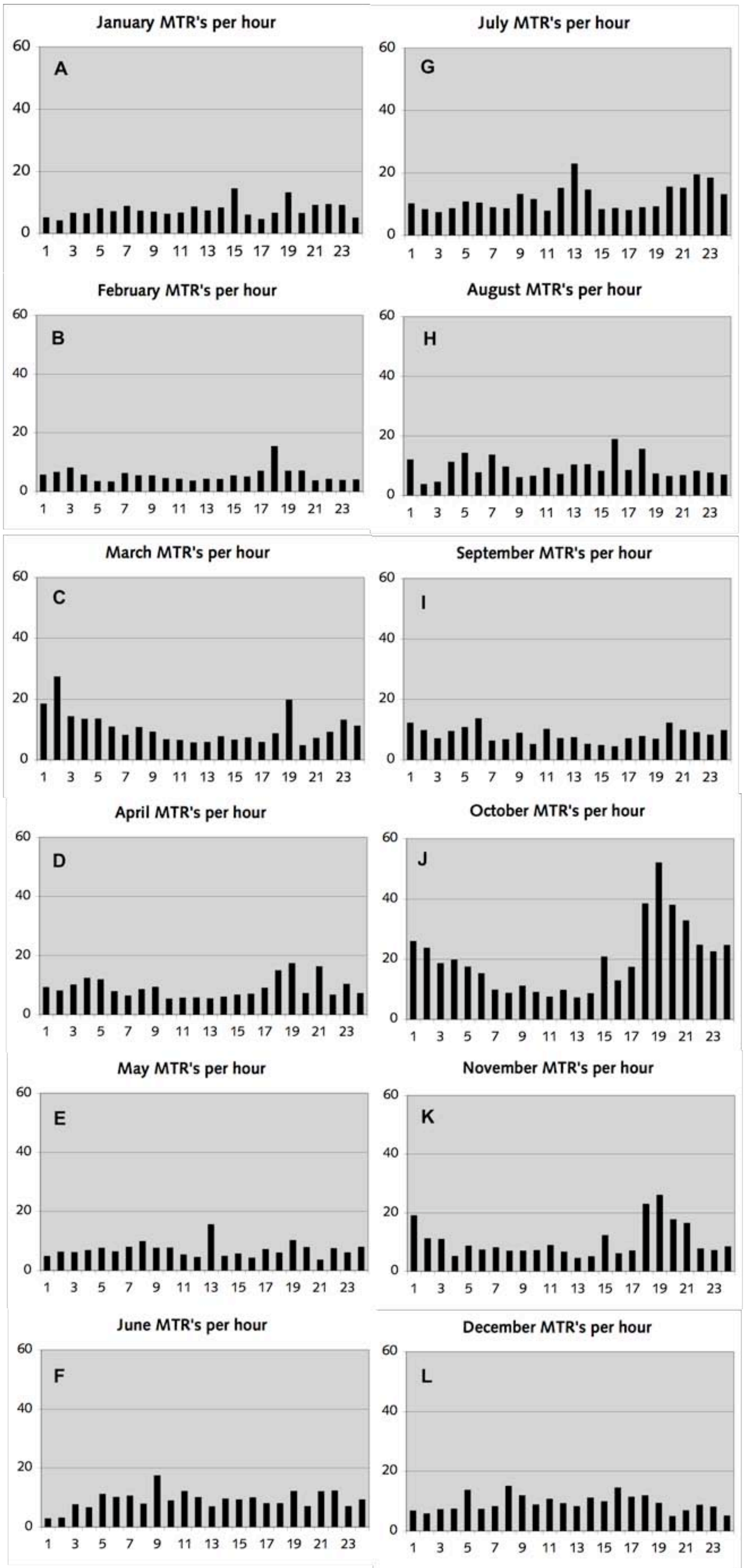


Figure 4.3 Diurnal patterns in mean traffic rate (MTR in #/km/hr) for the different months in 2008 (A-L). Data averaged for the entire month.

Fluxes on four typical days

In general, fluxes are expected to be low in summer and winter and higher during spring and autumn migration. However, migration mostly occurs in brief bouts of very high activity that occurs on days/nights with favourable wind (and weather) conditions. Focussing on large-scale average patterns as done in the graphs above does give good insight in overall fluxes in the area, which is relevant to assess the effect of the wind farm on bird populations. However, by lumping together the many nights with little or no (migratory) activity with those few nights on which migration peaks, we loose the insight in what happens on those days/nights that migration does peak. Thus, by zooming in on specific days in each season gives a better insight in the flight patterns that occur when there is high migratory activity.

Doing so, in every season four 'typical' days were selected and analysed in more detail. These days are representative of the processes occurring in these seasons (migration, winter visitors, summer breeders/non-breeders). All these twenty-four-hour-periods were days on which fieldwork was done, in order to have both visual and radar data.

In figure 4.4 total fluxes for these days are shown as well as fluxes separated into day and night. Fluxes measured on these four days are in line with the hypotheses:

• Winter	lowest MTRs	more diurnal movements
• Summer	slightly higher MTRs	more diurnal movements
• Spring	high MTRs	more nocturnal movements
• Autumn	highest MTRs	more nocturnal movements

Below, each date is examined in more detail. Note that the following graphs have different Y-axis values.

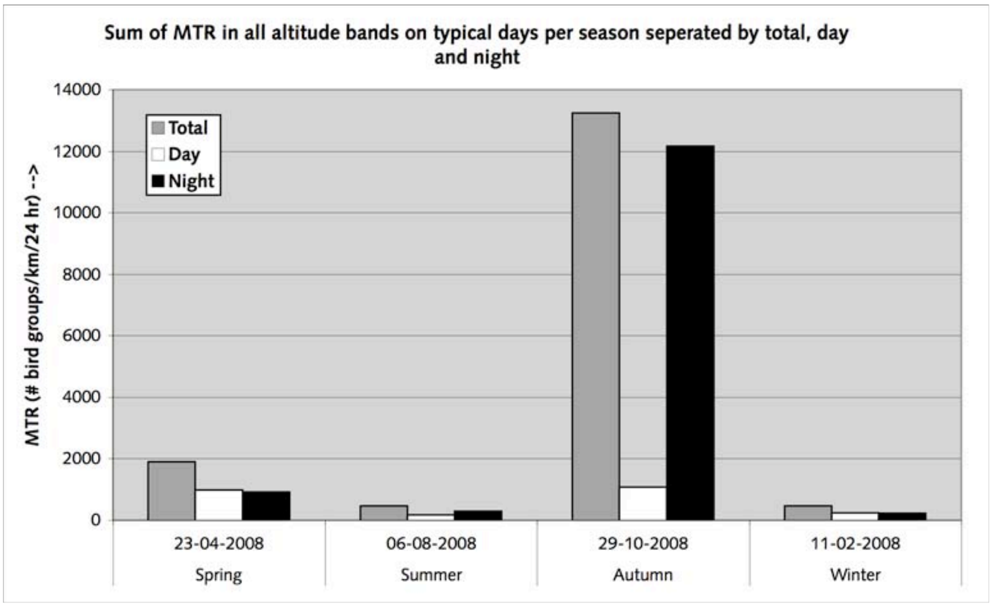


Figure 4.4 Summed fluxes (Mean Traffic Rates) during day (white bars) and night (black bars) and total (grey bars). Data for all altitudes combined and averaged over the day, as measured by vertical radar.

In **summer**, fluxes were intermediate (fig. 4.4), reflecting mainly local flight movements of gulls and cormorants. These birds use the wind farm for foraging and roosting and are throughout the year these birds are mostly observed.

A typical summer day was the observation day of the 6th of August 2008 with SE 3-4 Bft wind and overcast (20°C). On this day small numbers of several gull species (mainly lesser black-backed gull and herring gull) were present in the area with in addition some terns and cormorants. The evening panorama scans yielded most birds. Looking at the vertical radar data most bird groups were recorded in the morning and evening as well (fig. 4.5). These probably reflected flight activity of gulls going to and coming from the roosting areas. In the evening birds tended to fly higher at less risky altitudes compared to the morning. Quite high numbers still occurred in the late evening. Generally lowest numbers of flying birds were recorded in the period after midnight and at midday (9:00 – 11:00 GMT = 11:00 – 13:00 local time). On this summer day the MTR reached up to ca. 35 bird groups/hr/km in around dusk.

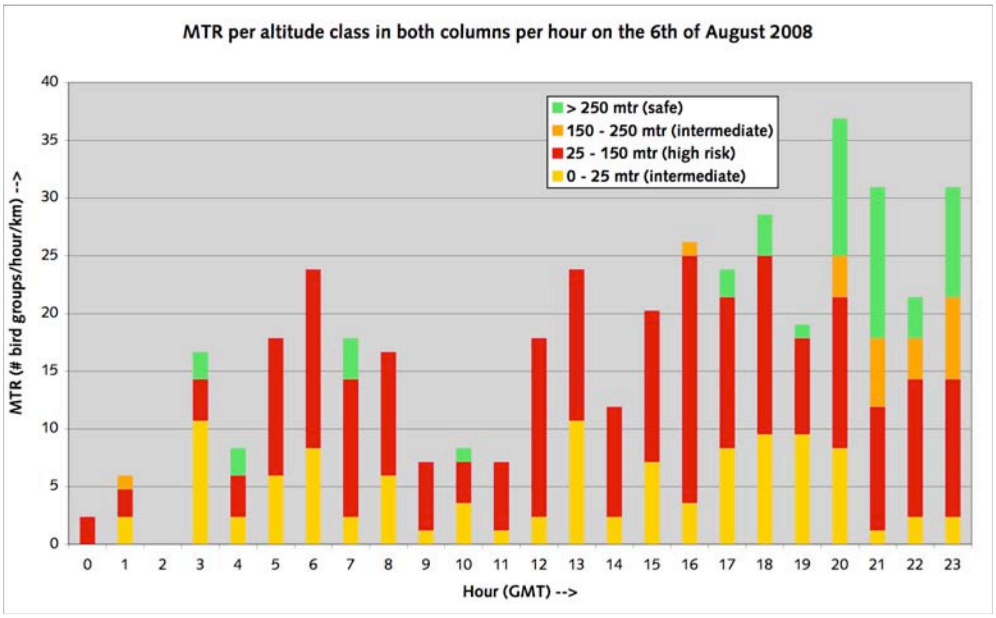


Figure 4.5 *Mean fluxes during the 6th of August 2008. Data are split in 4 risk classes. High risk at the altitude of the rotor blades at 25–150 m, intermediate risk below (0–25m) and above rotor blades (150–250 m) and low risk above 250 m.*

In **winter**, fluxes were relatively low, reflecting mainly local flight movements of gulls and cormorants. A typical winter day was the observation day of the 11th of February 2008 with SE 2 Bft wind and clear sunny skies (8°C). On this day some groups of geese, duck, divers and alcids were recorded although not all within range of the vertical radar. Looking at these data again highest numbers occurred in the morning (fig. 4.6). Flight activity slightly increased in the evening. Lowest numbers of birds were recorded in the afternoon. Late in the evening most birds flew at lower, more risky altitudes. Generally in winter high altitude movements were sporadically found. On this winter day the MTR reached up to ca. 70 # bird groups/hr/km in just after dawn.

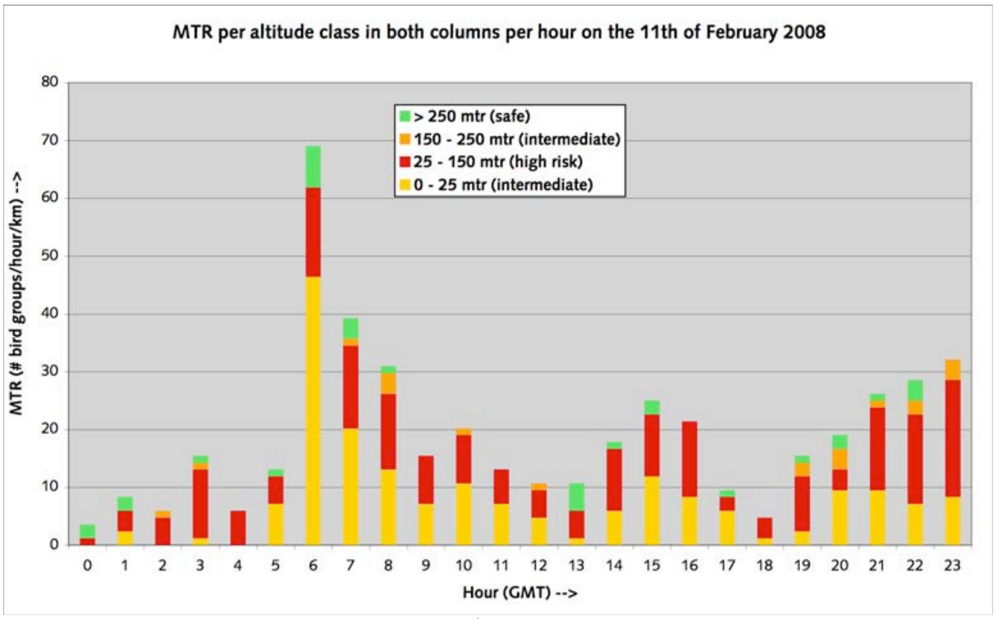


Figure 4.6 Mean fluxes during the 11th of February 2008. Data are split in 4 risk classes. For risk classes see subscript fig. 4.5.

In **spring**, MTRs were only slightly elevated (fig. 4.4) and much less distinct than in autumn. A typical spring migration day/night was the observation day of the 23rd tot the 24th of April 2008 in which fieldwork was carried on the metmast. These days a variable wind (SE – SW) of 1-3 Bft and a temperature up to 10°C was measured. Short periods of drizzle occurred during the evening. In the evening large groups of little gull were recorded with in addition large numbers of large gulls flying west. High numbers of migration started after 0:00 GMT. Almost no sounds were audible but some songbirds and gulls were recorded.

The vertical data show that the night before high numbers of high altitude migration was found (fig. 4.7). In the night that fieldwork was carried out, more movements occurred at high-risk altitudes. Differences in wind were distinct between the two nights with a westerly 5 Bft. during the night of 22nd to 23rd of April and a north westerly wind 3-4 Bft. during the night of the 23rd tot 24th of April. Possibly these differences in wind direction and speed might have influenced the chosen flight altitude. The night of the 22nd to the 23rd of March the MTR reached up to ca. 350 # bird groups/hr/km. This was a night with mainly high altitude movement of probably thrushes.

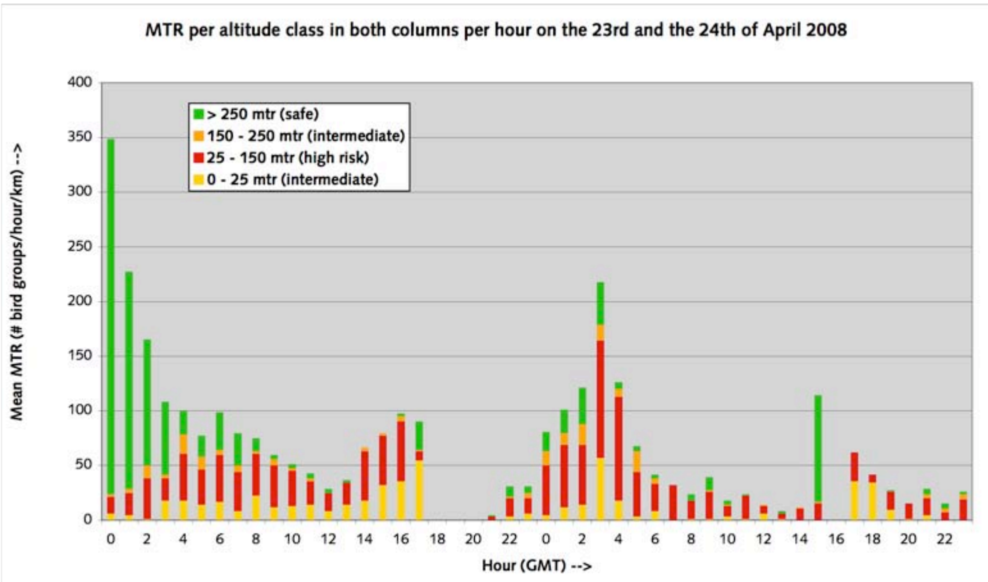


Figure 4.7 Mean fluxes on the 23rd and 24th of April 2008. Data are split in 4 risk classes. For risk classes see subscript fig. 4.5.

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. A typical autumn migration day/night in which fieldwork was carried out was the observation night of the 6th to the 7th of November 2008. This night bird numbers were quite low. In order to get a representative insight in an autumn migration night the night of the 29th and the 30st of October was taken for analysis (fig. 4.8). Unfortunately no fieldwork data for the night exist, as weather conditions did not allow a visit to the metmast. Based on timing of year, weather conditions and field reports from various birding websites this night probably followed a pattern more or less similar to the night of the 6th of November 2008 in which high numbers of thrushes like redwing, blackbird and song thrush were heard throughout the night. These birds all started to fly immediately after dusk. In the course of the night, flux decreased in a similar way as reflected on the vertical radar. On the 30st of October we were able to visit the metmast and observed a lot of goose (brent geese) and songbird (thrushes, starling) migration in the area. Locally large groups of kittiwakes were present as well. On this autumn night the MTR reached up to ca. 2600 bird groups/hr/km in just after dusk.

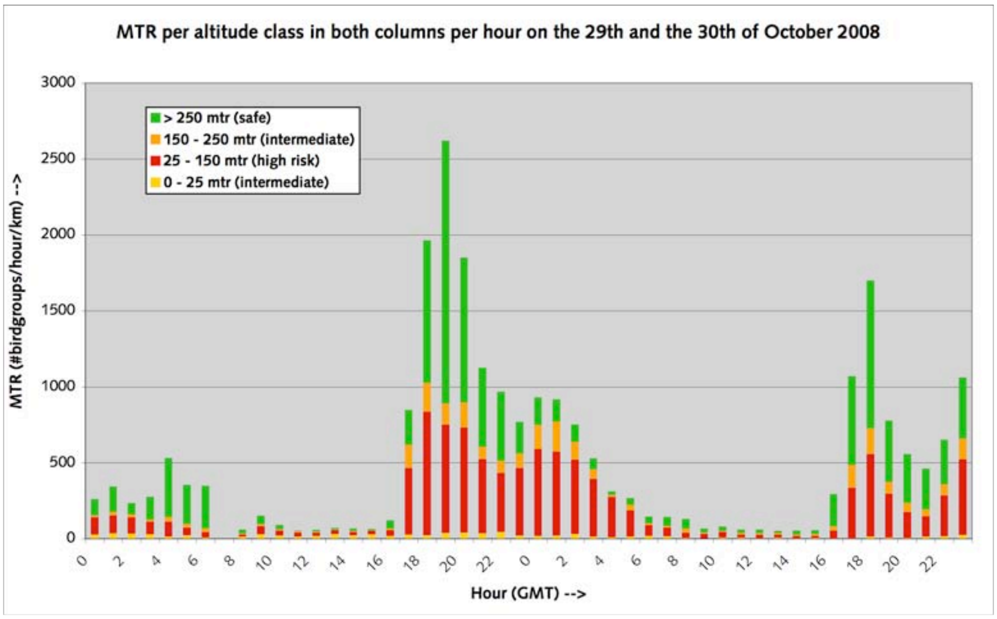


Figure 4.8 Mean fluxes on the 29th and 30th of October 2008. Data are split in 4 risk classes. For risk classes see subscript fig. 4.5.

4.2 Species-specific patterns (from visual observations)

In this paragraph, data from visual observations is presented. Panorama scans were carried out each hour during observation days on the metmast and give insight in the species flying in the wind farm area, as well as the abundance of these species and their flight directions (see ch 5) and altitudes (see ch 6) (see §2.3.1 and 2.3.2 for description of methods).

4.2.1 Species encountered in the wind farm area

A total of 101 bird species were seen during visual observations at the metmast (table 4.2). In addition, harbour porpoise, harbour seal and grey seal were encountered.

4.2.2 Species-specific flight activity (panorama scans)

Abundance

The total number of birds was low in all seasons compared to numbers counted during the baseline study (table 4.3; see Krijgsveld *et al.* 2005). The mean density of all birds combined rarely exceeded 1 bird per km^2 and the maximum density of individual species was 2,0 birds per km^2. The most common species were great cormorant, herring gull, lesser black-backed gull, common gull, kittiwake, unidentified (large) gulls and starling (all > 0,1 birds/km^2). Scoters, divers and alcids were absent or very scarce throughout the period. Compared to the baseline study the densities of alcids and gulls were lower overall. Great cormorants were considerably more numerous. Highest numbers of herring gull and lesser black-backed gull were present in summer. Great cormorants were most numerous in summer and common gulls and kittiwakes in winter.

The highest numbers of birds were encountered during winter (fig. 4.9). Especially common gull and kittiwake were numerous in this period. In spring many gannets and waders were recorded during panorama scans. Terns were most numerous during summer migration. Landbirds were most numerous during autumn migration. Cormorants (figs. 4.9 & 4.10) showed a gradual increase in numbers from the start of the study in February 2007 to September 2007. Initially numbers decreased again in autumn and early winter, but then were high again in January-March 2008. In summer 2008, numbers showed a steady decline after June, and numbers continued to be low the remainder of the year. Apparently not only breeding birds venture out to the wind farm, but also wintering birds started to do so.

Table 4.2 List of bird and mammal species observed visually at the metmast in the period February 2007 - December 2008.

group	subgroup	species	group	subgroup	species
divers		black-throated diver	terns		arctic tern
		red-throated diver			black tern
grebes		great crested grebe			common tern
tubenoses		northern fulmar			sandwich tern
gannets		northern gannet			tern spec
cormorants		great cormorant	alcids		guillemot
		European shag			razorbill
geese & swan	swans	swan spec.	raptors & owls		goshawk
	anser geese	bean goose			hen harrier
		greylag goose			kestrel
	branta geese	barnacle goose			marsh harrier
		goose spec.			merlin
		dark-bellied brent goose			peregrine falcon
sea ducks		common scoter			sparrowhawk
		eider	landbirds	other large birds	carrion crow
		velvet scoter			collared dove
other ducks	swimming duck	Eurasian wigeon			grey heron
		mallard			homing pigeon
		northern pintail			jackdaw
		northern shoveler			pigeon spec.
		teal		medium passerine	blackbird
	diving ducks	scaup			fieldfare
	mergansers	goosander			redwing
		red-breasted merganser			song thrush
		duck spec.			starling
waders		bar-tailed godwit			thrush spec.
		calidris spec.		small passerines	black redstart
		common ringed plover			blackcap
		dotterel			chaffinch
		dunlin			chiffchaff
		Eurasian curlew			gold crest
		Eurasian golden plover			house martin
		greenshank			meadow pipit
		grey plover			northern wheatea
		lapwing			pied wagtail
		little stint			pipit spec.
		oystercatcher			robin
		purple sandpiper			siskin
		red knot			skylark
		sanderling			songbird spec.
		wader spec.			stonechat
		whimbrel			swallow
		woodcock			swift
skuas		arctic skua			waxwing
		great skua			willow warbler
gulls	large gulls	black-backed gull spec.			yellow wagtail
		great black-backed gull			
		herring gull	sea mammals		grey seal
		lesser black-backed gull			harbour porpoise
	small gulls	black-headed gull			harbour seal
		common gull			
		kittiwake			
		sabine's gull			
	little gull	little gull			

Table 4.3 Species composition and mean density of birds (number of birds per km^2) as observed during panorama scans. Maximum densities are given in bold and blue. Empty cells indicate that the species was not seen in the area in that season; values of >0 indicate that the species has been seen in very low densities. For each season the respective number of scans is given in brackets.

			mean density (birds/sqr. km)				
group	subgroup	species	spring (n=108)	summer (n=103)	autumn (n=63)	winter (n=46)	total (n=320)
alcids	alcids	guillemot	>0			**0,01**	>0
		razorbill	>0		>0	**0,01**	>0
		razorbill/guillemot	>0			**0,00**	>0
cormorants	cormorants	great cormorant	0,15	0,10	**0,21**	0,18	0,15
divers	divers	diver spec.		**>0**		>0	>0
		red-throated diver		>0		**0,01**	>0
gannets	gannets	northern gannet	0,05	**0,06**	>0	0,01	0,04
geese & swans	branta geese	dark-bellied brent goose	0,01	0,01		**0,08**	0,02
	unidentified geese	goose spec.				**0,00**	>0
grebes	grebes	great crested grebe	**>0**				>0
gulls	large gulls	black-backed gull spec.	0,01	**0,06**	0,01	0,01	0,03
		greater black-backed gull	0,07	0,04	0,01	**0,31**	0,08
		herring gull	0,03	**0,32**	0,08	0,22	0,16
		large gull	0,16	0,36	**0,46**	0,33	0,31
		lesser black-backed gull	0,07	**0,32**	0,29	0,01	0,19
	small gulls	black-headed gull	0,01	0,03	0,05	**0,06**	0,03
		common gull	0,03	0,08	>0	**2,03**	0,29
		kittiwake	0,16	0,01		**0,95**	0,18
		little gull		**0,17**		0,01	0,06
		sabine's gull	**>0**				>0
		small gull	0,01	>0		**0,17**	0,02
	unidentified gulls	gull spec.	0,02	0,01		**0,12**	0,03
landbirds	large passerines	carrion crow		**>0**			>0
	medium passerines	blackbird	**>0**				>0
		redwing	**>0**				>0
		song thrush	**>0**				>0
		starling	**0,49**	0,10	>0	0,02	0,21
		thrush spec.	**0,02**				0,01
	other large birds	grey heron			**0,00**		>0
		homing pigeon	**>0**	>0			>0
		jackdaw	**>0**				>0
	small passerines	chaffinch	**>0**	>0			>0
		house martin		**>0**			>0
		meadow pipit	**>0**				>0
		pied wagtail	**>0**				>0
		pipit spec.	**>0**				>0
		skylark	**>0**				>0
		songbird spec.	>0	**>0**			>0
		swallow		**0,01**			>0
		yellow wagtail	**>0**				>0
other ducks	diving ducks	scaup		**>0**			>0
	mergansers	goosander				**>0**	>0
		red-breasted merganser	>0	**>0**			>0
	swimming ducks	northern pintail	**0,01**				>0
		teal		**>0**			>0
	unidentified ducks	duck spec.	>0		**>0**		>0
raptors & owls	raptors & owls	goshawk	**>0**				>0
		kestrel		**>0**			>0
		marsh harrier			**>0**		>0
		merlin		**>0**			>0
sea ducks	sea ducks	common scoter	>0	**0,04**	>0	>0	0,01
		eider	**>0**			>0	>0
		velvet scoter		**>0**			>0
skuas	skuas	arctic skua	>0	**>0**			>0
terns	terns	arctic tern		**>0**			>0
		black tern		**>0**			>0
		common tern		**>0**	>0		>0
		common/arctic tern	>0	**>0**	>0		>0
		sandwich tern	0,01	0,01	**0,06**		0,02
		tern spec	**>0**	>0			>0
tubenoses	tubenoses	northern fulmar	>0	>0		**0,01**	>0
waders	waders	calidris spec.		**>0**			>0
		dunlin		**0,01**			>0
		Eurasian curlew			**>0**		>0
		eurasian golden plover		**>0**			>0
		grey plover		**>0**			>0
		oystercatcher			**>0**		>0
		wader spec.		**>0**			>0

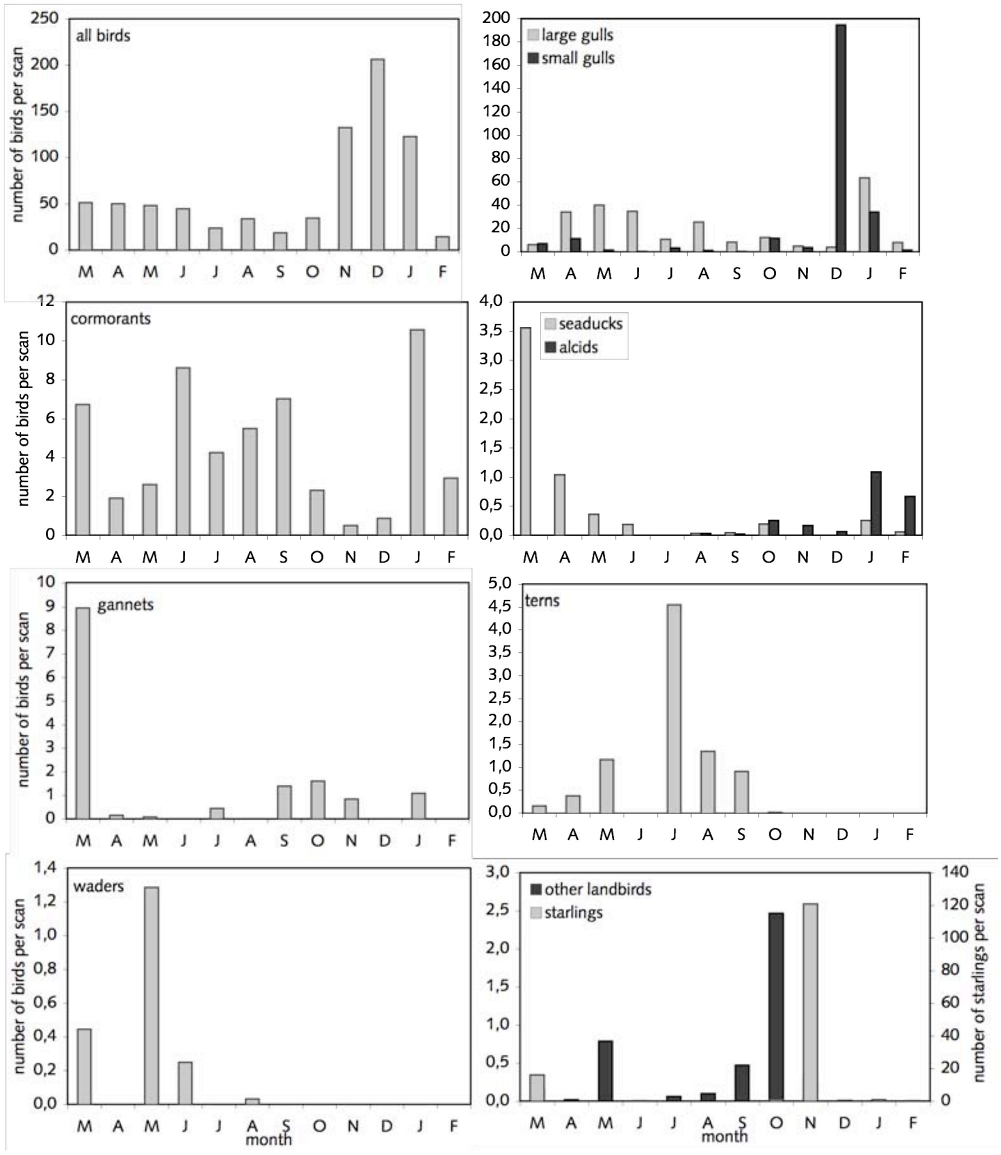


Figure 4.9 *Number of birds seen per panorama scan, averaged per month, for 2007 and 2008 combined, shown for various species/-groups.*

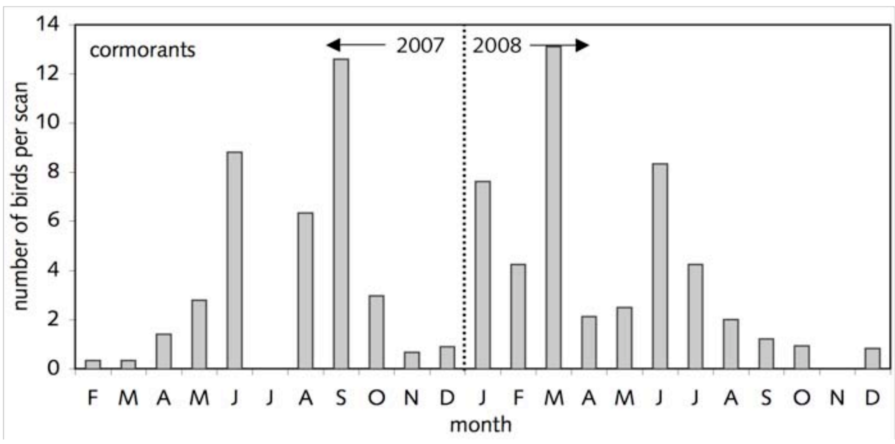


Figure 4.10 *Number of cormorants seen per panorama scan, averaged per month and shown for all months throughout the study period from February 2007 to December 2008.*

Distribution of species in the wind farm area

The distribution of birds around the metmast is visualised is figure 4.11. The highest numbers were present in sector 1 (north-north-west). Lowest numbers were recorded in sector 7 (east-north-east). Among the species groups that were abundant in the area, gannets showed the strongest avoidance of the wind farm. The relatively high numbers of small gulls in sector 4 and 8 are due to high numbers of kittiwakes foraging in this area close to the metmast in autumn. Cormorants and gulls showed no avoidance of the wind farm, but numbers were not higher in the wind farm either. Terns were mostly migrating birds, that foraged en route. They were regularly seen flying and foraging inside the wind farm.

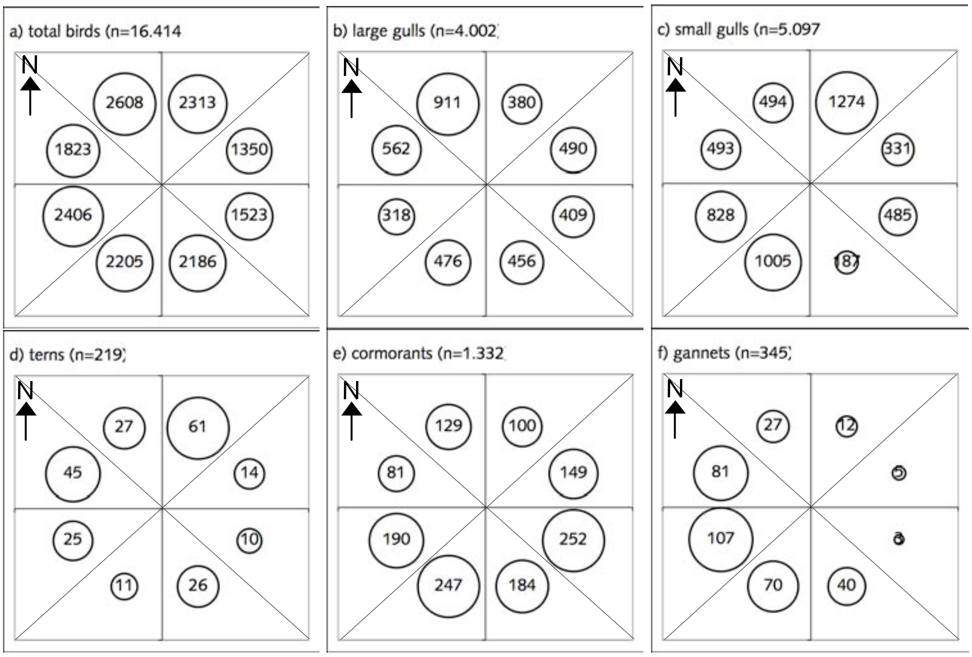


Figure 4.11 Distribution of birds around the metmast (situated in the centre) as observed during panorama scans. Birds seen up to 3 km away from the metmast are included in this graph. The wind farm is situated in the upper right diagonal – see fig. 2.2 for situation.

The distribution pattern of birds present in the wind farm area appears to be influenced by the presence of the wind farm (fig. 4.11). Overall, less than 30% of the most abundant bird species were recorded inside the wind farm (fig. 4.12). This proportion is remarkably low, given that the wind farm covers close to 50% of the scanned area, and distribution would therefore be 50/50 if no avoidance occurred. This indicates that the birds in general were avoiding flying between the turbines of the wind farm. This is remarkable given the fact that the most abundant species such as gulls and cormorants did not show a clear avoidance of the wind farm in their flight paths (see §5.2). When the observations are rounded off and the data are complete, the distribution of birds in relation to the wind farm will be analyzed statistically to evaluate distribution patterns. Again, gannets in particular showed a strong preference for the area outside the wind farm.

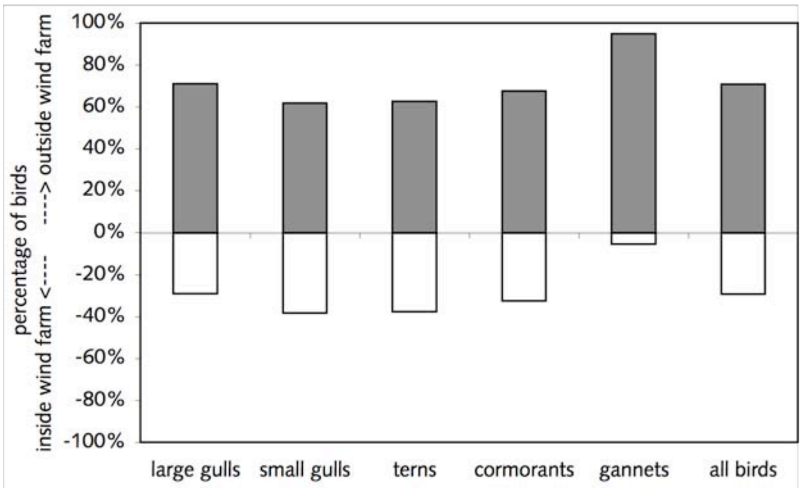


Figure 4.12 Relative distribution of several species within and outside the wind farm. Given the layout of the wind farm within the observed area, the proportion of birds inside the wind farm should be appox. equal when no avoidance occurs. Note that all species presented occurred in higher percentages outside the wind farm.

4.3 Nocturnally flying species

To gain insight in species composition of birds flying through the area at night, visual and audio observations of birds flying during the night were undertaken in October 2007 and March, April, September and November 2008. Visual observations were undertaken through moonwatching (§4.3.1) and audio observations through detection of nocturnal calls (§4.3.2) by experienced fieldworkers.

4.3.1 Moonwatching observations

Moonwatching observations were analysed for two nights in autumn. Despite the fact that numbers are low and do not give a representative image of the local situation yet, they do give a relevant view of species flying through the wind farm area on migration nights. Additional efforts will be made in the spring of 2009 to obtain more data on nocturnal species distribution. During the moonwatching efforts, a total of eleven birds were recorded during 110 minutes of observations. The numbers of birds recorded in each species group during each observation period are shown in figure 4.13. Although conditions for moonwatching were not ideal on 2 October 2007, the moon being in the last half and with an overcast sky, a total of six migrating birds were still recorded in three ten-minute recording periods. A total of eight ten-minute periods of observation were carried out on 17 September 2008, during this time five birds were recorded. With the exception of a record of two pigeon species during the latter visit, all records were of single birds.

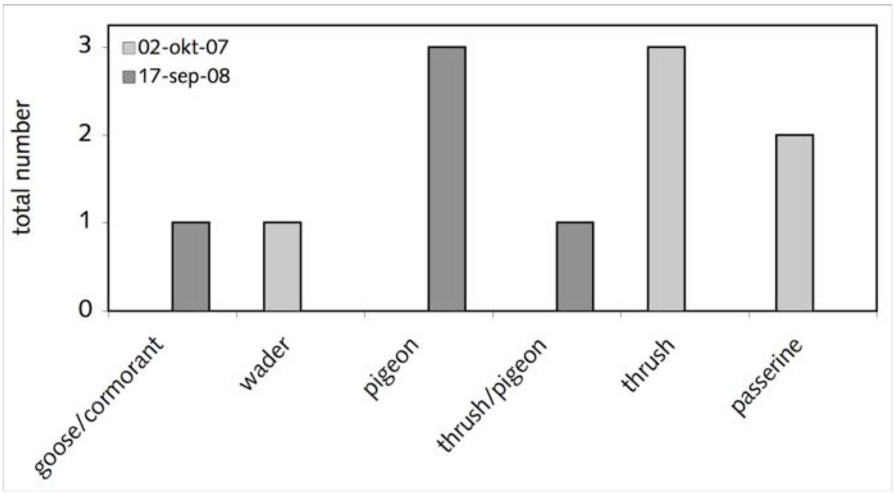


Figure 4.13 Numbers of birds (by group) recorded during 2 autumn moonwatching observations.

4.3.2 Nocturnal calls

Calls of birds during dark were recorded on five nights. Observations were carried out on 2-3 October 2007 and 27-28 March, 23-24 April, 17-18 September and 6-7 November 2008. Observations were carried out for a total of 1600 minutes and birds were recorded in 35% of the five-minute observation periods. Birds were recorded more frequently in spring (41% of five-minute periods) than in autumn birds (33% of five-minute periods).

A total of 876 birds of eleven species were recorded during nocturnal observations, the majority of these (85%) being thrushes (redwing, song thrush and blackbird) (fig. 4.14). Although most birds were recorded in autumn, a greater number of species were recorded during spring (fig. 4.15). Thrushes constituted 95% of all birds recorded in autumn, whilst in spring this figure was 40%. The mean flock size of thrushes (based on the number of calls heard) was larger during autumn (5,4 birds/flock) than in spring (2,1 birds/flock).

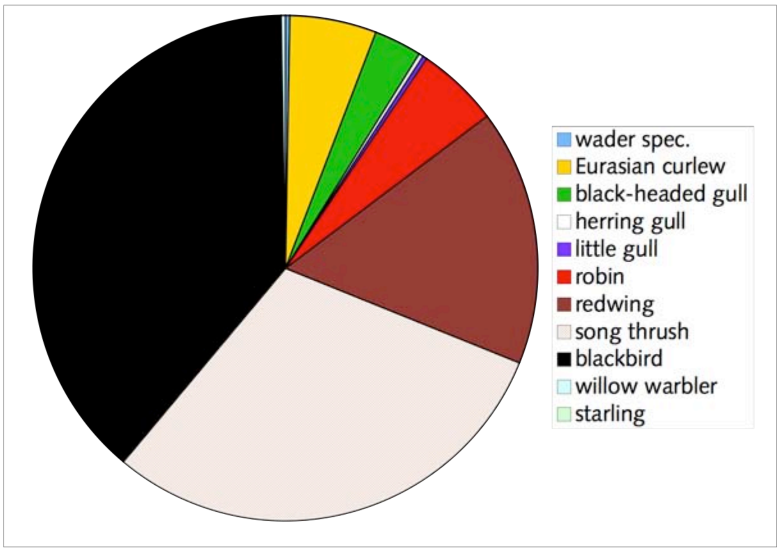


Figure 4.14 Species composition of birds recorded during nocturnal audio observations on 5 nights between October 2007 and November 2008.

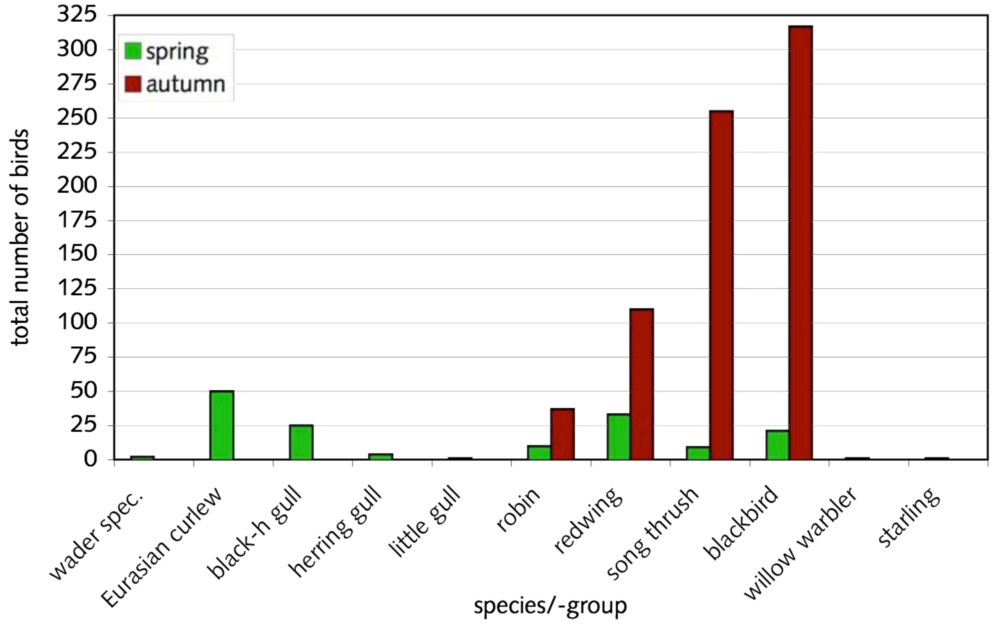


Figure 4.15 Total numbers of birds for each species/-group recorded during spring and autumn nocturnal observations.

The numbers of birds recorded varied during the night from 0 to 403 birds per hour (fig. 4.16). Between eight and five hours before 00:00 GMT the mean number of birds per hour was 16. The level of activity fell to a mean of 5 birds per hour between four hours before and 00:00 GMT before rising again to a peak of 403 birds per hour four hours after 00:00 GMT. These figures are largely influenced by numbers recorded during autumn. With the exception of four hours before 00:00 GMT and five hours after 00:00 GMT thrushes were recorded during every hour of nocturnal observations and constituted the majority of birds in each hourly period. The numbers of both small passerines and gulls peaked during four hours after 00:00 GMT whilst wader numbers peaked one hour earlier.

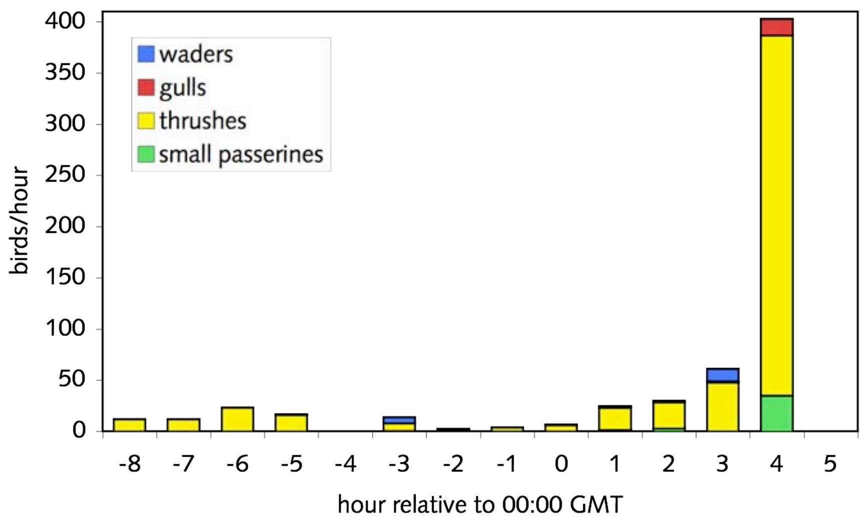


Figure 4.16 Total number of birds in each species group recorded per hour in relation to 00:00 GMT.

Throughout the night, more birds were recorded in autumn than in spring (figs. 4.17 & 4.18). Both in spring and autumn, peak activity was recorded during four hours after 00:00 GMT. However, over ten-times more birds were recorded during this period in autumn than in spring (371 birds per hour compared to 32 birds per hour); most of this was due to thrushes. This was largely due to high numbers being recorded on 3 October 2007.

In autumn, the pattern of activity throughout the night largely reflected that in figure 4.16, with the fewest calls recorded between four hours before 00:00 GMT and 00:00 GMT before numbers increased to peak at four hours after 00:00 GMT (fig. 4.17). Only thrushes (redwing, song thrush and blackbird) and small passerines (robin and starling) were recorded during autumn.

In spring, most calls were recorded after 00:00 GMT (fig. 4.18). Calls were identified as being from waders (Eurasian curlew and unidentified wader species), gulls (black-headed gull, herring gull and little gull), thrushes (redwing, song thrush and blackbird) and other small passerines (robin, willow warbler and starling). Most activity of gulls was recorded during four hours after 00:00 GMT. During this period gulls constituted approximately half of all birds recorded.

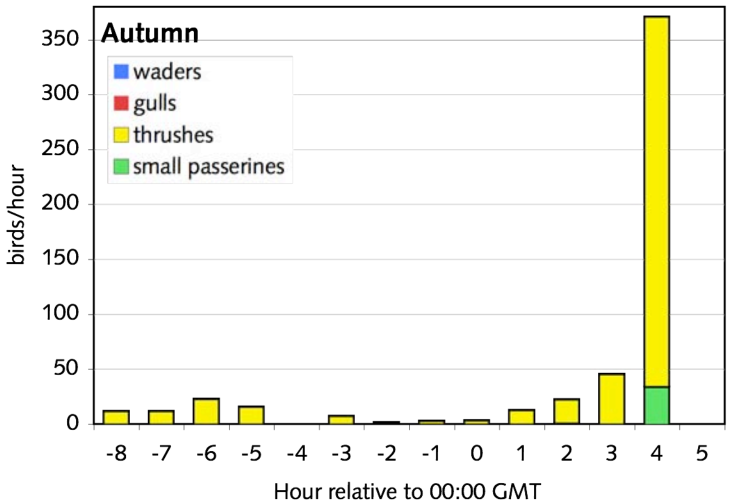


Figure 4.17 Total number of birds in each group recorded per hour in relation to 00:00 GMT during autumn, as recorded by ear at night.

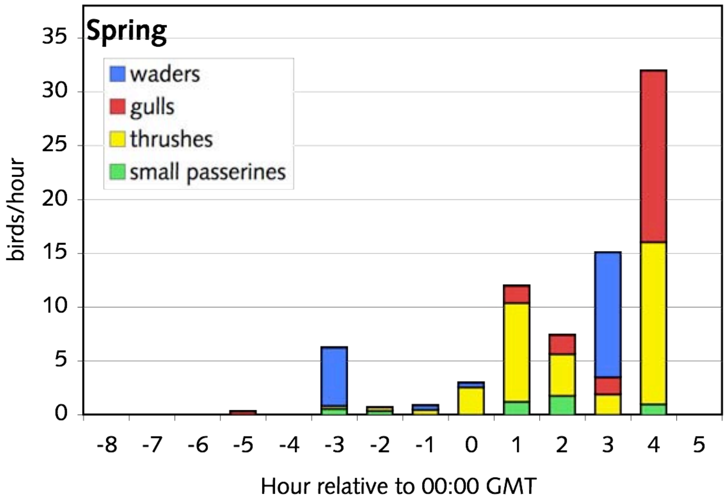


Figure 4.18 Total number of birds in each group recorded per hour in relation to 00:00 GMT during spring, as recorded by eat at night.

Patterns of thrush migration

The pattern of thrushes recorded throughout the night differs in spring and autumn (figs. 4.17 & 4.18). The peak of thrush activity was recorded during four hours after 00:00 GMT during both spring and autumn, however, in autumn more birds were also recorded prior to four hours before 00:00 GMT, while in spring a second peak of activity was noted one hour after 00:00 GMT. These differences may be indicative of patterns of thrush migration.

In general thrushes migrate at altitudes of below 2500 m (Eastwood 1967) and at speeds of between 39 and 50 km/h (Alerstam *et al.* 2007) and typically at night. During spring, the records of thrushes at the metmast from 00:00 GMT onwards coincides with birds leaving the eastern UK, approximately 200km away, from dusk onwards. The peak during four hours after 00:00 GMT could be indicative of birds decreasing their altitude during dawn as they search for land where they can rest and feed. Furthermore, studies have shown that flight altitudes are, on average, lower during day than during night (Eastwood 1967; Wernham *et al.* 2002).

The pattern during autumn of relatively few calls detected through the night compared to the peak at four hours after 00:00 GMT can be explained by the relatively high altitude of thrushes during migration (Eastwood 1967, tailwinds) as they leave the Dutch coast, which may reduce the likelihood of birds being detected by call. Again as dawn approaches birds decrease their altitude in search of land and during this time birds that have started to cross the North Sea may return to the Dutch coast. As the pattern of numbers in autumn are largely influenced by observations from 3 October 2007 further observations of nocturnal movements will be required to validate these findings.

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 fieldwork (§5.2). See chapter 2 for an outline of the various subjects and the first interim report (Krijgsveld *et al*. 2008) for additional data on this subject.

Summary of results
Compared to the first interim report, we here present extensive data on flight paths that were collected from raw radar data. These provide a valuable database to relate the results obtained from processed radar to and give clear insights in avoidance patterns around the wind farm. Second, the dataset on flight paths of individual species was extended considerably in 2008, providing good insight in avoidance behaviour and avoidance distances of a large number of species.

5.1 General patterns from horizontal radar data

Patterns from Furuno raw radar
To validate the flight paths recorded with Merlin radar system, we have visually recorded data from the Furuno radar screen. These data give an accurate image of flight paths of birds, because clutter and birds can easily be recognized visually and consequently the database consists of birds only. However, the database is limited to those days (and nights) on which visual observations were done at the metmast, in contrast to the continuous monitoring of the horizontal radar. Below we present some preliminary results from these data.

The numbers of observation days for which data are presented are four in winter, six days and three nights in spring, five days in summer, nine days and four nights in autumn.

Overall. Flight directions around the wind farm indicate that birds are avoiding the wind farm to some extent (figs 5.1-5.4). The general pattern that emerges is that close to the wind farm birds change their flight direction away from the wind farm. Once they've passed the wind farm, they return to their original direction. A considerable percentage of birds thus seems to fly around the wind farm. This pattern will be further analysed for the final report.

This pattern seems to be more evident during day than during night time (e.g. spring day versus spring night, fig 5.2). This would be in line with birds detecting the wind farm better during day than night, and also with birds flying at higher altitudes during the night and passing the wind farm well above rotor height (see §6.1).

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 occurrence 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.

Winter. Flight paths in winter mainly reflect activity of gulls, because gulls were the most abundant species in winter (see §4.2.2). Flight paths were predominantly westward (fig 5.1), which is in line with visual observations of larger gulls. Within the wind farm, flight directions appear to be more to the northwest. Possibly this is a result of the orientation of the wind farm: birds may fly parallel to the turbine lines rather than crisscrossing through the farm.

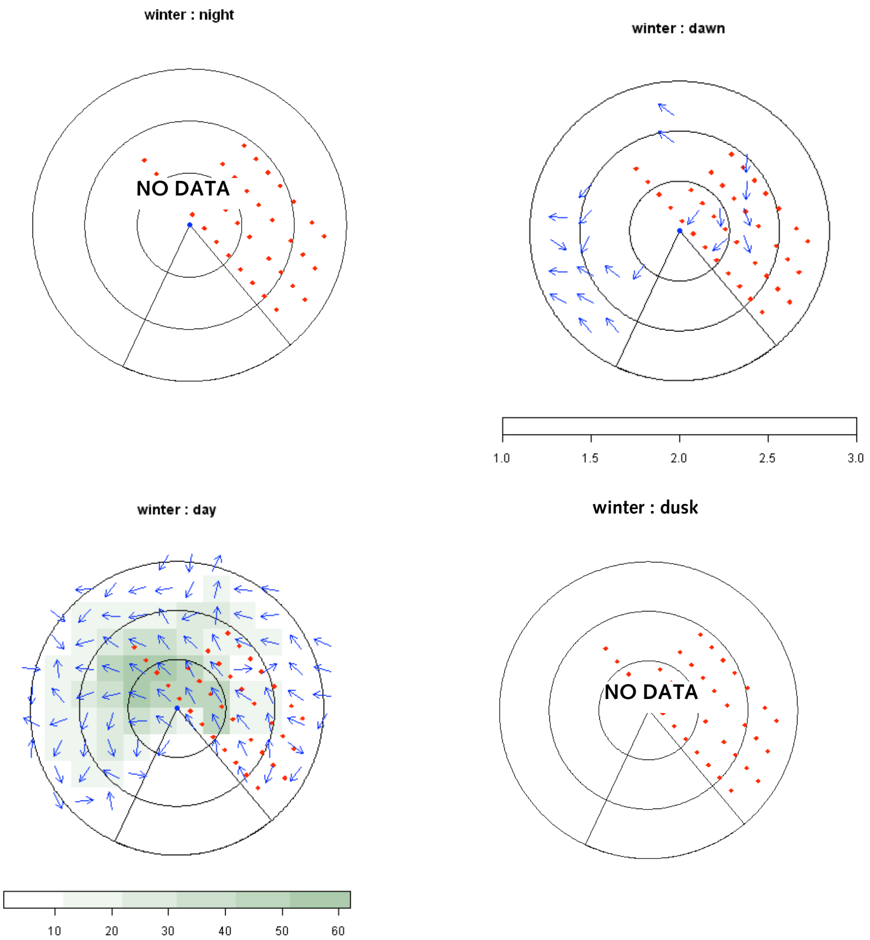


Figure 5.1 Flight direction and intensity of birds in ***winter****, in relation to position to the wind farm. Data shown for both night, dawn, day and dusk. Data recorded manually from Furuno raw radar images. Flight directions are indicated by the blue arrows. Number of tracks per gridcell indicated by the intensity of green colouring; legend given in the bar below each graph, referring to the number of tracks counted in total and thus serving as comparison of activity within the graph, not between graphs. Directions in the outer boundaries are based on a limited number of data only and therefore are more random.*

Spring. Flight paths largely reflect migrating landbirds (fig. 5.2). That the mean flight direction at night was straight eastward indicates that during the observation nights migration mainly was of birds flying in from England. At night and dawn flight directions indicate less avoidance than during the day. During the day, birds were heading more in northwesterly directions, and more avoidance occurred. Directions within the wind farm were more or less random. Possibly tracks within the wind farm are of non-migrating species such as gulls and cormorants that are foraging within the wind farm.

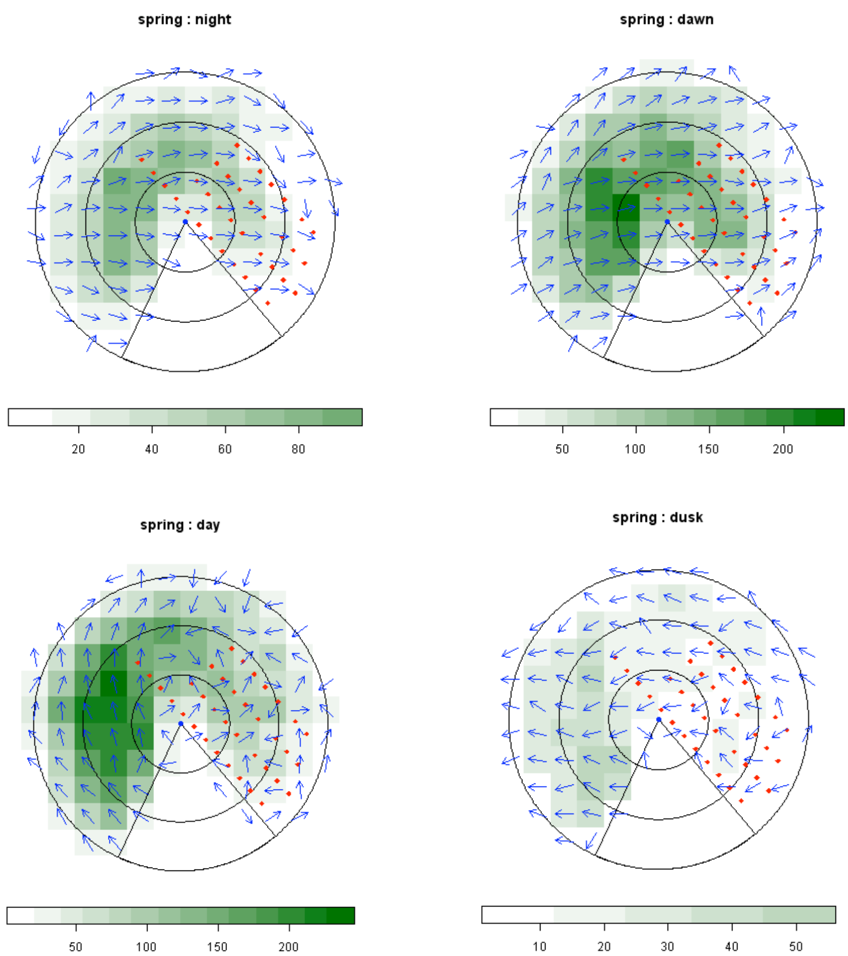


*Figure 5.2 Flight direction and intensity of birds in **spring**, in relation to position to the wind farm. Data shown for both night, dawn, day and dusk. Data recorded manually from Furuno raw radar images. Legend see fig. 5.1.*

Summer. For summer, flight paths that were recorded during daylight hours haven't been separated in dawn, day and dusk. The predominantly southward flight directions may therefore reflect gulls and or cormorants flying to the coast in the evening (fig. 5.3). Gulls were repeatedly seen flying in the direction of the Prinses Amalia wind farm (which is close to the OWEZ wind farm) in summer, and a roost of gulls was encountered here during ship-surveys (pers. comm. M. Poot). The combination of southward- and northwestward-flying birds may have resulted in the southwestward mean flight directions in the southwest of the wind farm. An alternative is that some early autumn migration already occurred in this period. Data have to be analysed in further detail to explain this pattern.

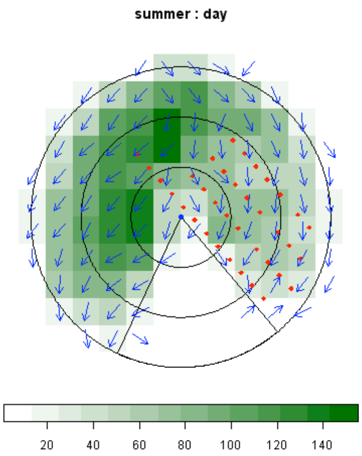


*Figure 5.3 Flight direction and intensity of birds in **summer**, in relation to position to the wind farm. Data shown for both night, dawn, day and dusk. Data recorded manually from Furuno raw radar images. Legend see fig. 5.1.*

Autumn. Main flight direction was south, reflecting mostly migrating landbirds (fig. 5.4). Directions were similar during day and night. Some avoidance is visible in diurnal flight directions. At dawn, correction flights toward the coast changed the mean flight direction toward east.

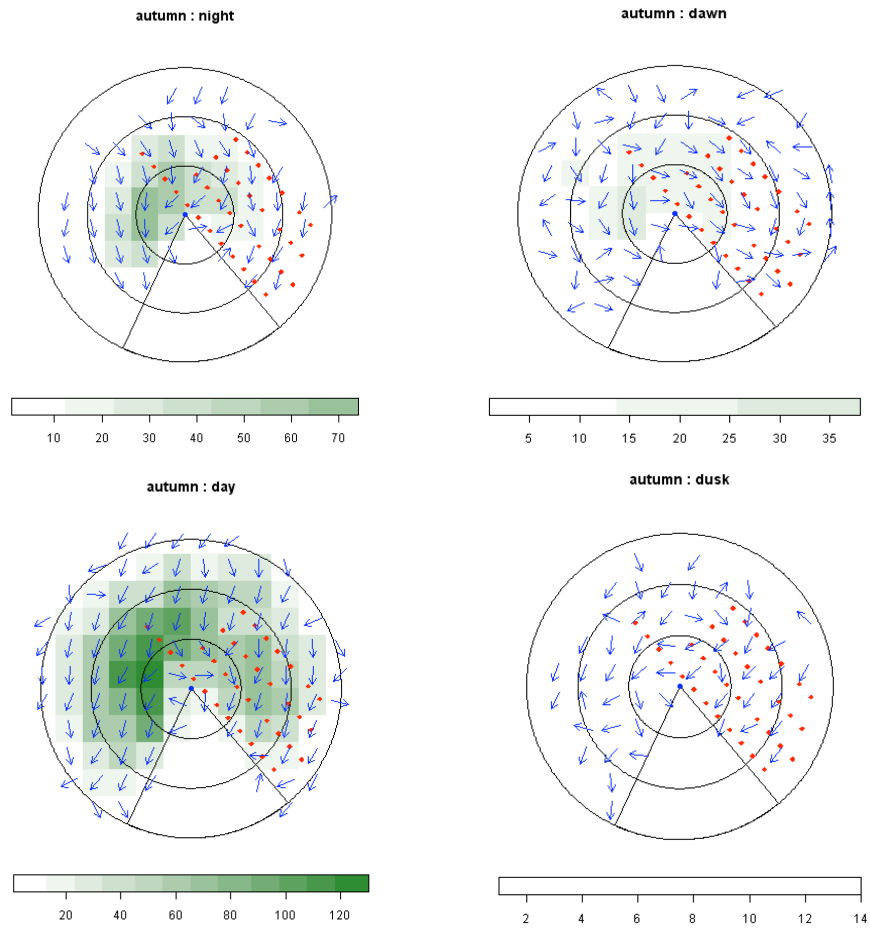


*Figure 5.4 Flight direction and intensity of birds in **autumn**, in relation to position to the wind farm. Data shown for both night, dawn, day and dusk. Data recorded manually from Furuno raw radar images. Legend see fig. 5.1.*

5.2 Species-specific patterns (from visual observations)

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

5.2.1 General flight directions of species present

The mean flight directions of the most common species groups as observed in the panorama scans is discussed below.

- *Inside* the wind farm (fig 5.5) the overall flight direction was more or less random. Large gulls were predominantly flying westward or eastward. The majority of terns flying inside the wind farm were heading south or west. Cormorants were not seen flying in westerly directions, possibly due to the fact that their occurrence in the area is related to the presence of the wind farm area. With the absence of fishing vessels in the area, cormorants probably do not venture out to sea much further than the wind farm.
- *Outside* the wind farm (fig 5.6) the overall flight direction was westerly. However, this figure is dominated by two large flocks of starlings heading west in the early morning (2nd November 2007). The flight patterns of the seabirds was more random. Especially large gulls and cormorants flew in all directions. An explanation for these random flight directions lies in the fact that most cormorants and gulls were foraging outside the wind farm (fig. 5.7). Gannets predominantly flew north when outside the wind farm.

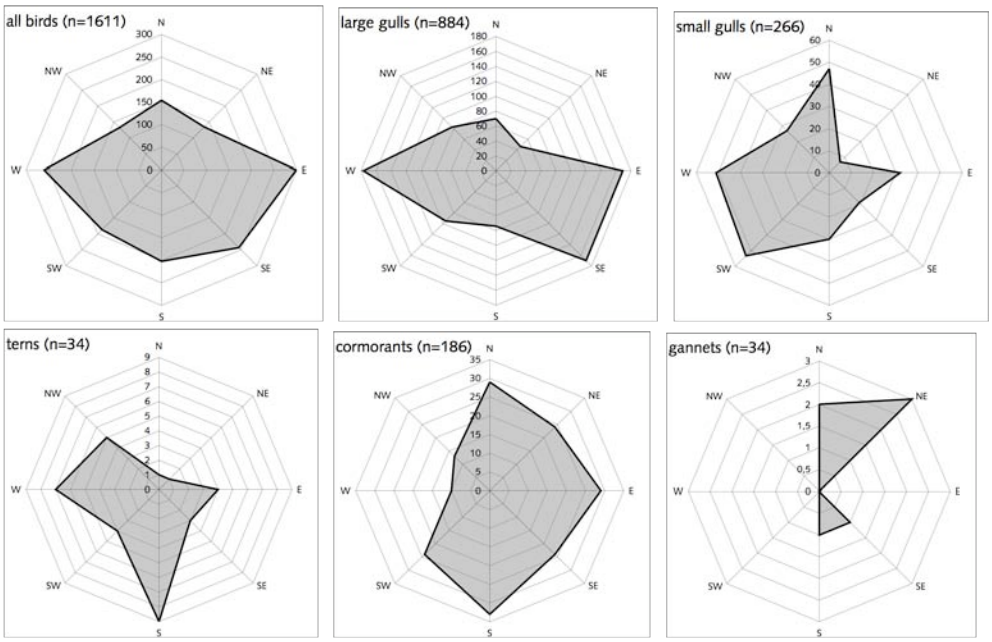


Figure 5.5 Flight directions ***inside the wind farm*** *of all birds and of species groups that were most common in the panorama scans, during daytime and for all seasons combined. Scale reflects the number of birds seen flying per direction for each of 8 directions. Scales vary between graphs; low number reflects low number of birds observed in panorama scans.*

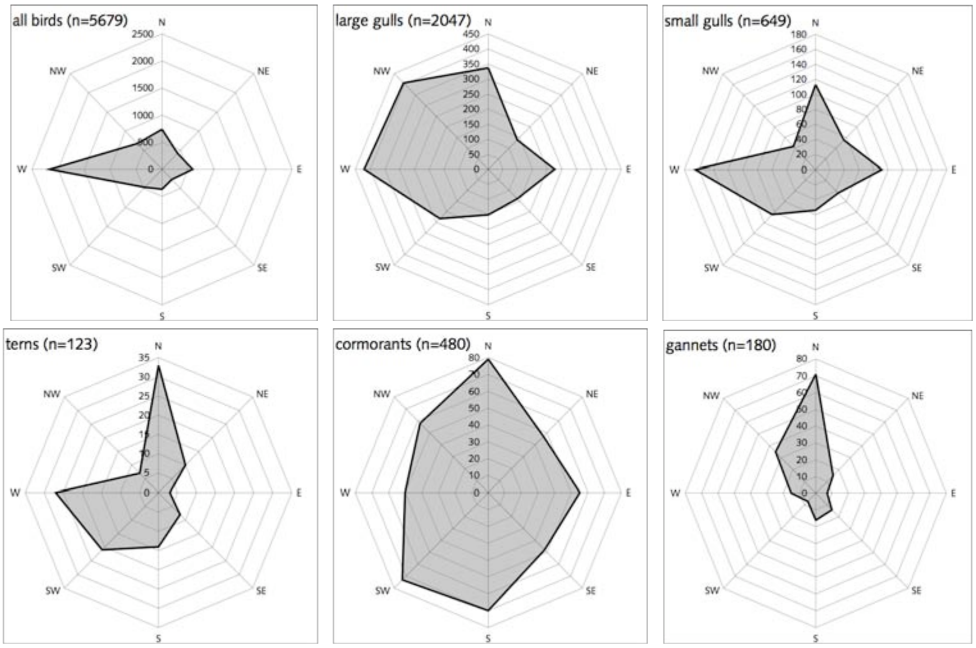


Figure 5.6 Flight directions ***outside the wind farm*** *of all birds and of species groups that were most common in the panorama scans, during daytime and for all seasons combined. Legend see fig. 5.5.*

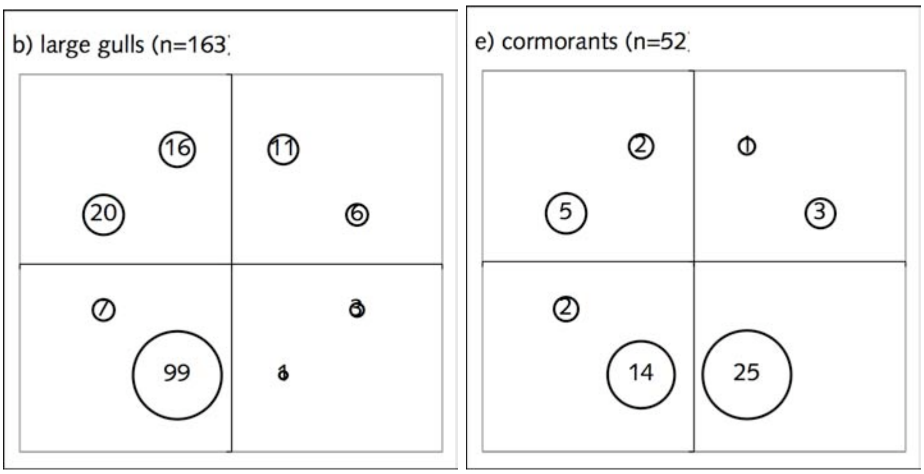


Figure 5.7 Distribution of ***foraging*** *cormorants and large gulls around the metmast, as observed in panorama scans. Because most of the foraging birds were counted outside the wind farm, this explains why flight directions of these groups are random outside the wind farm.*

5.2.2 Species-specific flight paths

Visual observations on flight paths of individual birds flying in the wind farm area yield additional information on occurrence of deflection. A total of 440 flight paths of 74 species groups were recorded through visual observation. The two species for which most flight paths were recorded are great cormorant and northern gannet, which together made up 25% of all tracks recorded. The group size of birds for which flight paths were recorded varied from 1 to 600 (for starling), while the mode for all observations was 1. A total of 112 flight paths of birds outside of the wind farm and 308 flight paths of birds inside the wind farm were recorded. The mean group size of birds for which flight paths were recorded was four inside the wind farm and eight outside the wind farm.

Of the flight paths that were observed, 30% of the bird groups did not fly through the wind farm, the remaining 70% did (table 5.1). Deflection, defined in this context as changing flight direction at close range from the wind farm, occurred in close to 50% of all bird groups. Deflection was highest in gannets, that approach the wind farm closely before changing direction, and in geese and swans. no deflection was observed in four groups of alcids. These birds are scarce in the wind farm area, and when they are seen, they usually fly by at large distances from the farm. The lack of deflection may in that sense be misleading. Alcids were generally not seen in the wind farm. Deflection is likely to occur at larger distances than can be overseen visually. Therefore radar observations will yield more insight in these patterns (final report 2010).

Table 5.1 Occurrence of avoidance and deflection around wind farm for various species groups. Shown is the percentage of bird groups that did not fly through the wind farm, as well as the percentage of bird groups that showed deflection around the wind farm. No of bird groups observed in total are shown in italics for both groups.

species group	% of groups not flying through wind farm	nr of groups observed	% of groups showing deflection	nr of groups observed
divers	33	*12*	29	*7*
grebes	0	*1*		*0*
gannets	69	*49*	87	*31*
cormorants	12	*57*	36	*47*
geese & swans	47	*19*	67	*12*
sea ducks	52	*23*	40	*15*
other ducks	29	*14*	56	*9*
waders	28	*18*	33	*15*
skuas	0	*4*	0	*2*
gulls	25	*101*	42	*73*
terns	22	*32*	38	*24*
alcids	0	*4*	0	*2*
raptors & owls	10	*10*	14	*7*
landbirds	19	*77*	42	*43*
all birds	29	*423*	45	*288*

Recorded flight paths are visualised in figures 5.8 through 5.11. A few patterns emerge from these data:

- Flight paths appear to be **concentrated** in the NW corner of the wind farm, between WT9 & WT10 (figure 2.2). This observation suggests that birds were avoiding the main body of the wind farm, but showed less hesitation to cross the single line of turbines. This line extends 2 km from the main body of the wind farm, so these birds were saving c. 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.

- **Gulls** did not show deflection when they were flying in the wind farm area (fig. 5.8). All observed species of gulls were regularly seen foraging or resting within the wind farm (little gull, kittiwake, black-headed gull, common gull, herring gull and both black-backed gulls).
- **Cormorants** were seen in the wind farm area throughout the study period (see fig 4.9). 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 as well. Cormorants were seen foraging for fish in the wind farm on a regular basis. No avoidance is visible in their flight paths (fig. 5.8).

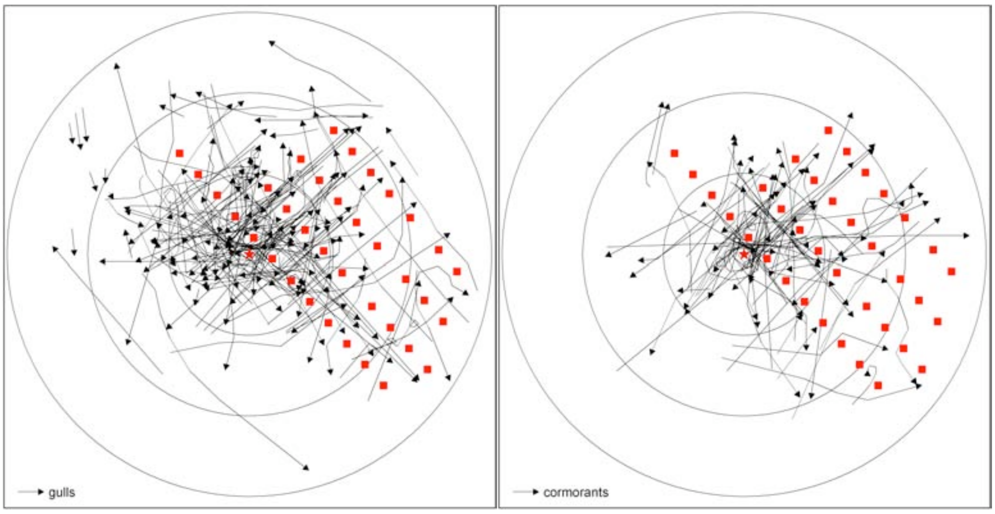


Figure 5.8 Flight paths of gulls (left) and cormorants (right) flying in the wind farm area. Data observed visually from the metmast (star in centre graph). Squares depict the turbines, rings are placed at intervals of 1 NM=1.85 km; max distance from metmast to farmost turbine is c. 5 km . Note the low level of avoidance in both species.

• **Seabirds** such as **gannets, auks, guillemots, divers, scoters and eiders** strongly avoided the vicinity of the wind farm (fig 5.9). Most of these birds were observed flying at large distances around the entire wind farm (scoters, alcids, divers; often too far away to record accurate flight paths) or deflecting upon approaching the wind farm (gannets). Only occasionally were birds of this group seen flying through the wind farm. On one occasion (winter '08-09) a pair of eiders was seen diving within the wind farm, and this same winter a few small flocks of guillemots were seen foraging in and near the wind farm. In general however these species stayed away from the wind farm.

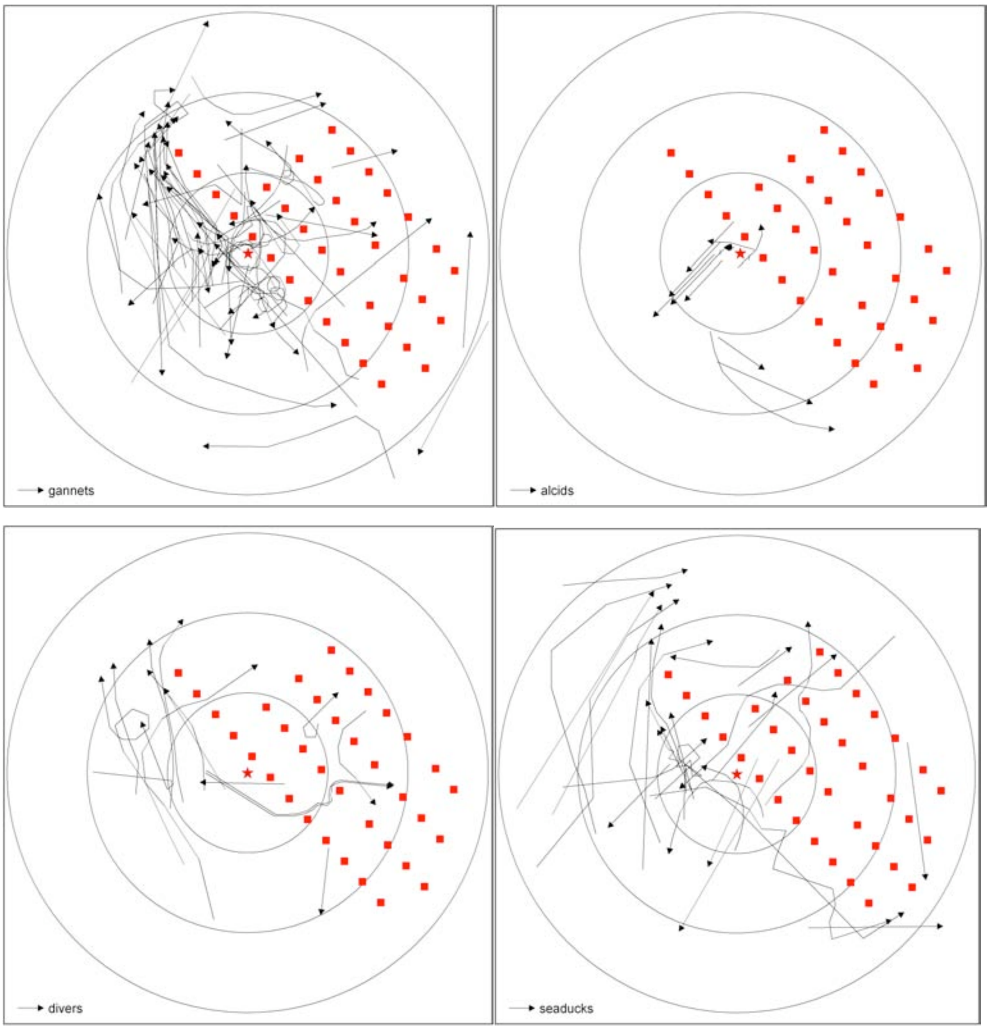


Figure 5.9 Flight paths of seabirds such as gannets (upper left), auks & guillemots (upper right), divers (lower left) and scoters & eiders (lower right) flying in the wind farm area. Legend see fig. 5.8. Note the high level of avoidance in this group.

- **Terns** and **skuas** migrating through the area or foraging in the area did not show avoidance (fig. 5.10). Terns were regularly seen foraging within the wind farm, and the few skuas that were seen showed no deflection at all.

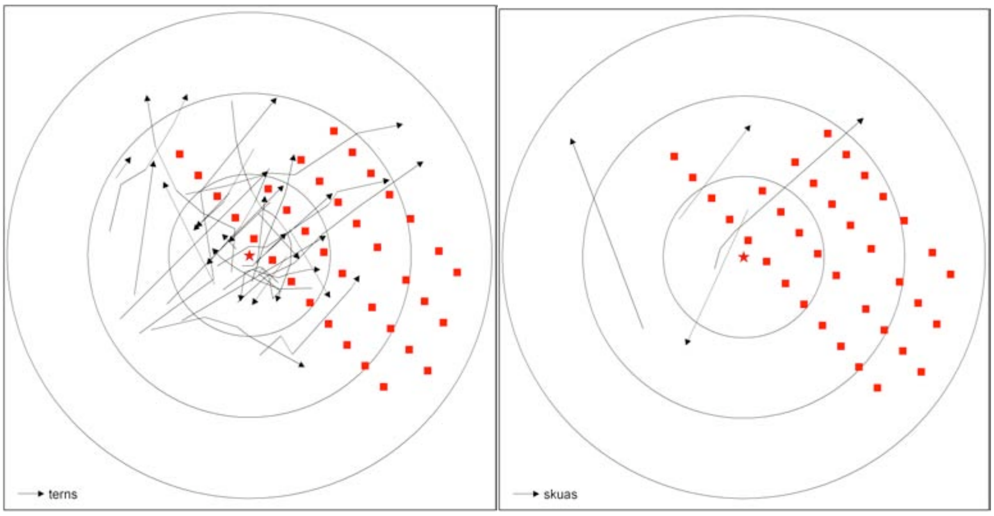


Figure 5.10 Flight paths of terns (left) and skuas (right) flying in the wind farm area. Legend see fig. 5.8. Note the low level of avoidance in these species.

- **Geese** and **swans** migrating to and from Britain strongly avoided the wind farm when they were flying at rotor height. It was observed repeatedly that flocks of geese flying at rotor height broke apart when arriving at the wind farm. The individual birds circled around in panic, and took some time before regrouping, after which they flew around the entire wind farm (fig. 5.11). Both swans and geese flying above rotor height did not show avoidance.
- **Ducks** other than seaducks showed some avoidance, but to a far lesser extent than seaducks (fig. 5.11).
- **Waders** that were migrating through the area generally flew above rotor height and did not show avoidance. Those birds that flew at rotor height showed some deflection in their flight paths, but often entered the wind farm (often at a location where a turbine was standing still) (fig. 5.11).
- Most observations of migrating **passerines** were of thrushes and starlings. No clear pattern is visible in this group (fig. 5.11). Both birds avoiding the wind farm and birds showing no avoidance were observed. In general, avoidance seems to be less strong than in other species such as seabirds and geese. Passerines showing avoidance tended to enter the wind farm after initial avoidance. A starling was seen flying towards the wind farm, and showing initial avoidance. Eventually it entered the wind farm, but with strong head winds it fell into the sea. The additional scare it perceived from the wind farm, on top of strenuous weather conditions, may have resulted in the exhausted bird giving up.
- A **peregrine falcon** was seen on several occasions. The bird (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. Other raptors that were seen (**marsh harrier, sparrow hawk, goshawk**) showed no strong avoidance.

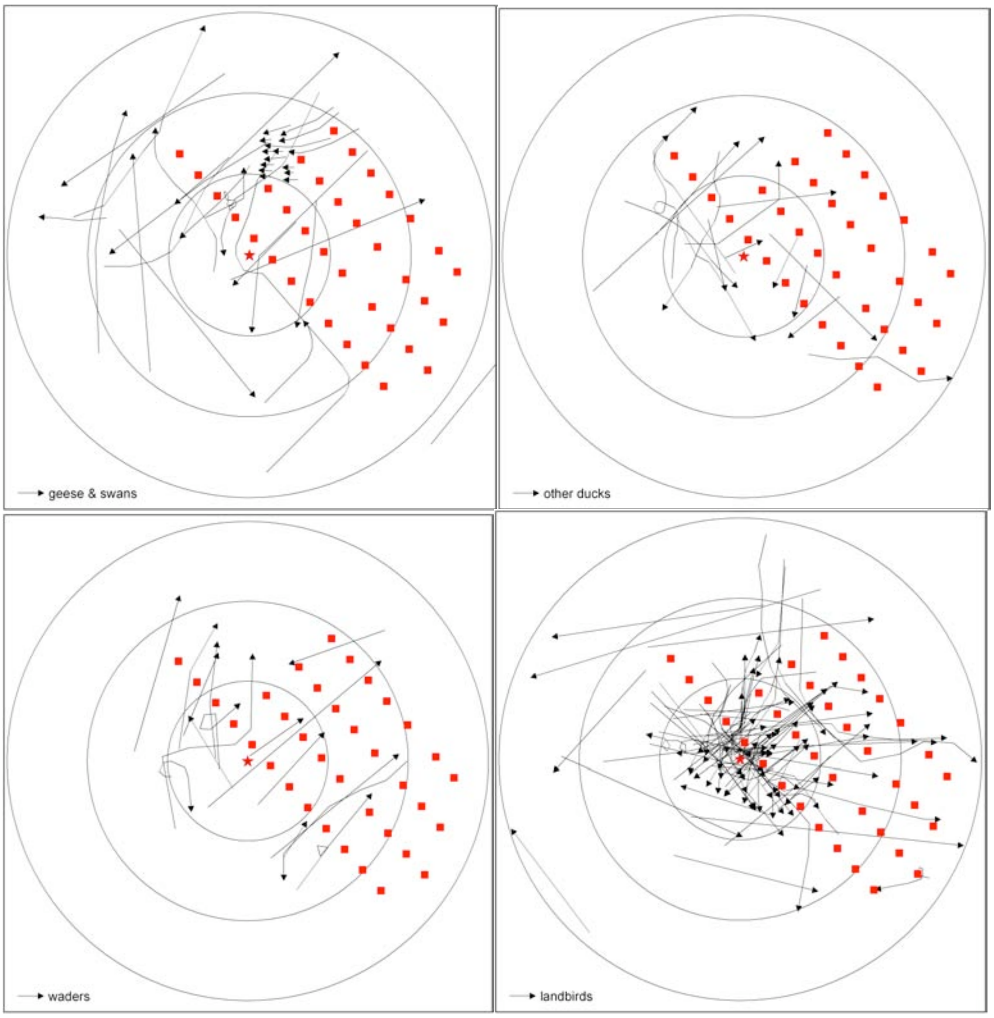


Figure 5.11 Flight paths of geese & swans (upper left), ducks other than seaducks (upper right), waders (lower left) and landbirds (lower right) flying in the wind farm area. Legend see fig. 5.8. Birds of this generally showed avoidance when flying at turbine height, not when above.

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 Britain. Photo's C. Heunks (peregrine) and K. Krijgsveld.

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 and provide data on flight activity up to altitudes of 1.5 km (0.75NM). In §6.2 data are presented on species-specific flight altitudes. These data are limited to much lower altitudes, as they were obtained by visual observations. Species-specific observations available from moon watching during nights in the migratory periods are described as well.

Summary of results
Flight activity was recorded at all altitude bands (measured up to c. 1500 m high). In the winter and summer season flight altitude was low, reflecting the dominance of gulls (and other local seabirds) flying at low altitudes. During migration, flight activity occurred at higher altitudes as well as at low altitudes, especially at night. When approaching the wind farm, birds generally increased their flight altitude, but altitude still was within the range of the rotor blades in general.

6.1 General patterns in flight altitude (from radar observations)

Collision 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 the general altitude at 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 birds 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. In this chapter flight altitude is analysed in more detail in 11 altitude bands. Every band represents 139 m altitude. The lowest altitude band was divided into 2 sub-bands (height 0.5 and height 1).

Altitude distribution of birds
Birds were found at all altitudes during all months (figs. 6.1-6.3). Both in 2007 and 2008 most birds occurred in the lowest altitude band (0–69 m altitude). Due to improved radar settings, fluxes were higher in 2008 than in 2007. Differences will be validated and corrected for in the final report. Some patterns emerge in the presented graphs that are related to the calibration process (little activity in low altitude bands in 2007) and reflect the current interim status of the analysis. We refer to the final report for the actual distribution of fluxes across altitudes. The data presented here can be used to interpret the general patterns.

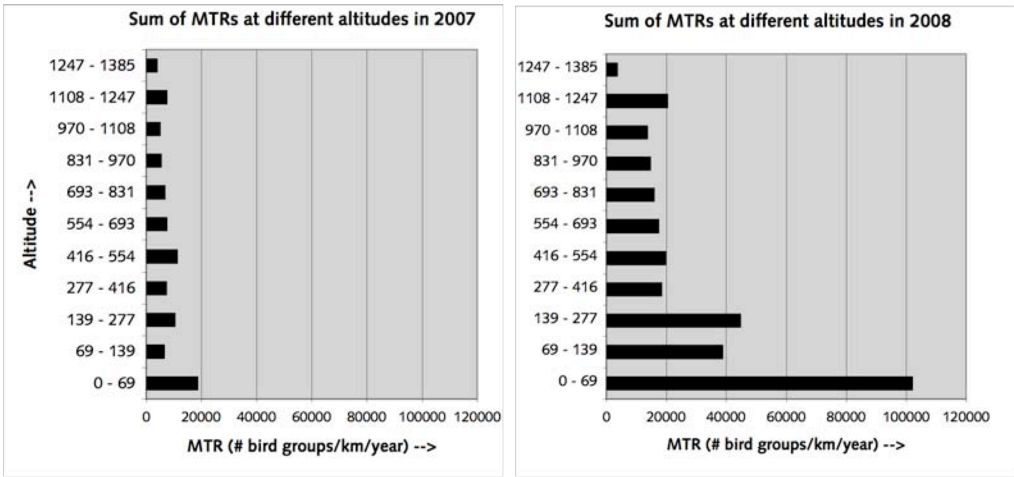


Figure 6.1 Sum of Mean traffic rates (MTRs, in # of bird groups/km/hr) in 2007 and 2008 at different altitudes.

Figure 6.2 (2007) and 6.3 (2008) show the altitude distribution at which birds fly during the different months of the study period, during the night and the day. Some remarkable results:

- Throughout the year flight activity of bird groups occurred at all altitudes.
- In both years December had high numbers of low altitude movements, reflecting high fluxes of seabirds (gulls) flying at low altitudes.
- In 2008 both migration periods (March/April and October/November) had higher numbers of movements at night than during the day, especially at higher altitudes. These movements will mostly be of waders and passerines (thrushes) on their way to the breeding and wintering grounds.

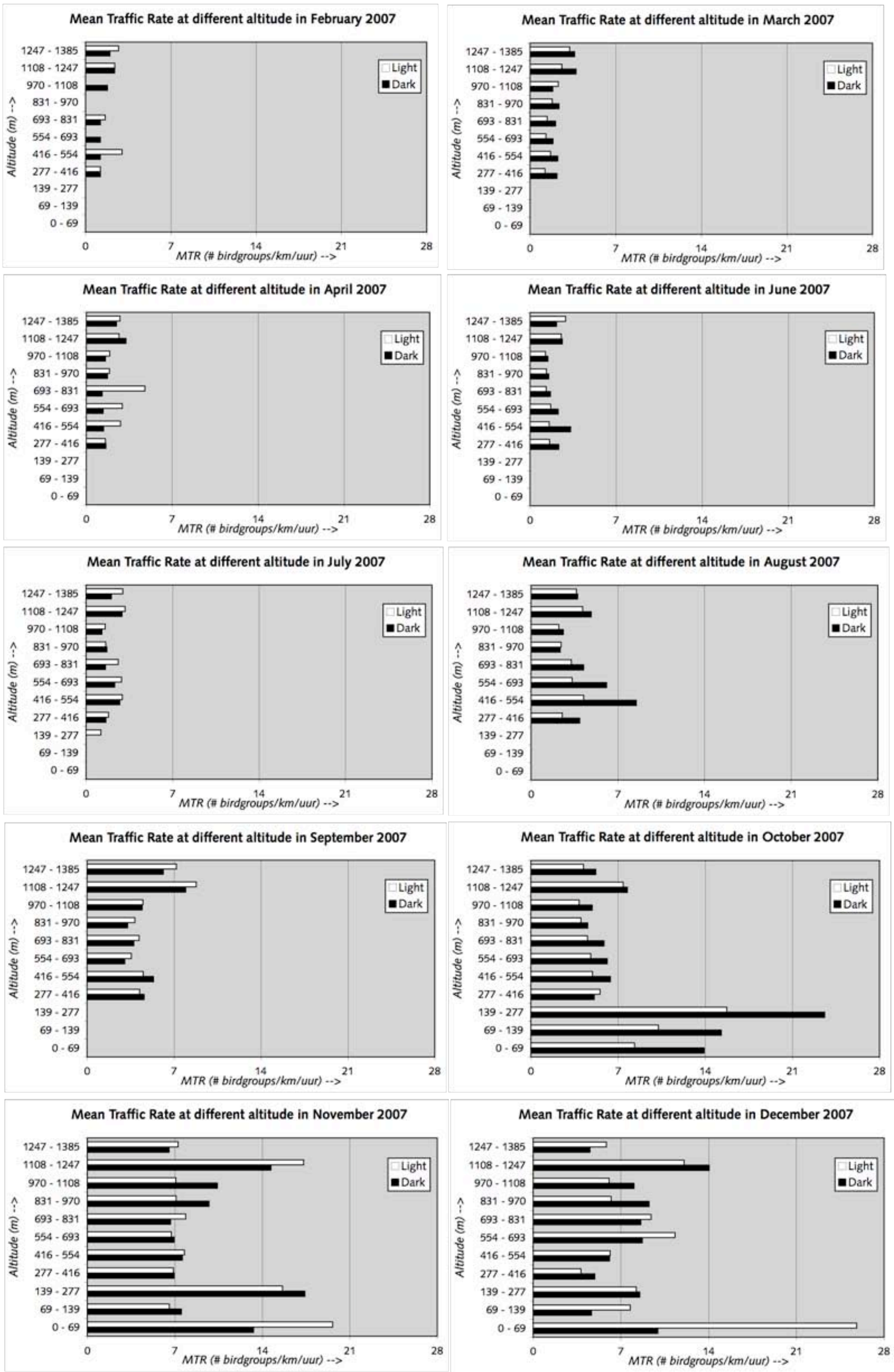


Figure 6.2 Mean traffic rate (MTR, in # of bird groups/km/hr) in 2007 at different altitudes split between day and night for the different studied months.

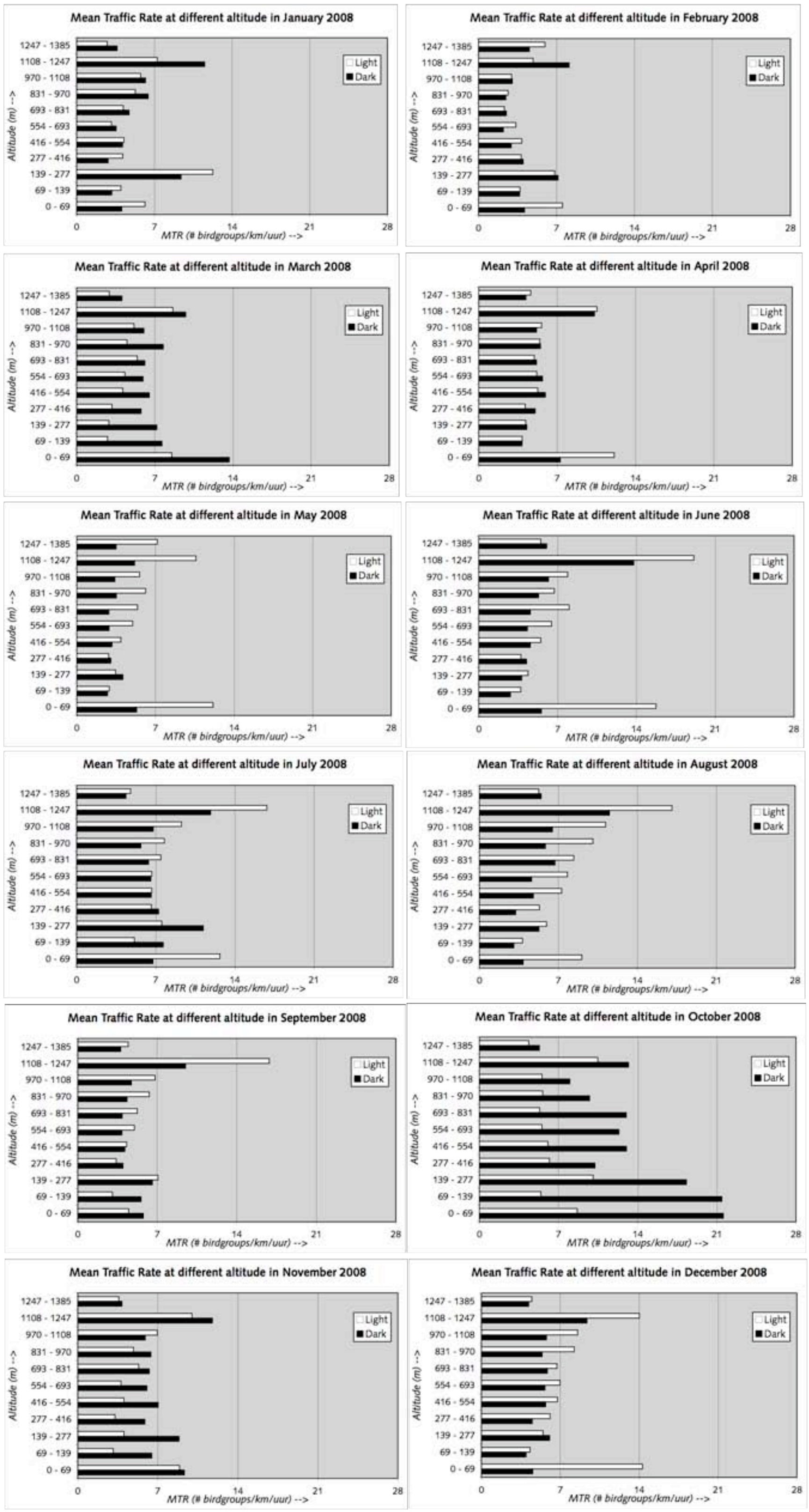


Figure 6.3 Mean traffic rate (MTR, in # of bird groups/km/hr) in 2008 at different altitudes split between day and night for the different studied months.

Flight altitudes on four typical days

In general, flight altitude is expected to be lower in summer and winter and higher during spring and autumn migration, as migrating birds tend to fly higher than local seabirds. Zooming in on specific days in each season gives a better insight in flight altitude patterns during the different seasons and during the day in and around the OWEZ wind farm. Four representatives days in the four seasons have been studied in more detail. These days are the same as those used in §4.1. In winter most (> 90%) flight movements were found in the lower altitude sections below 277 m (figure 6.3). In summer the same pattern was found with most (ca. 90%) movements at lower altitude except for the night period in which some more high altitude movements occurred. During migration more (ca. 50%) high altitude movements (> 277 m) occurred, especially at night (figure 6.3). In the text below each date is examined per hour in the course of the day.

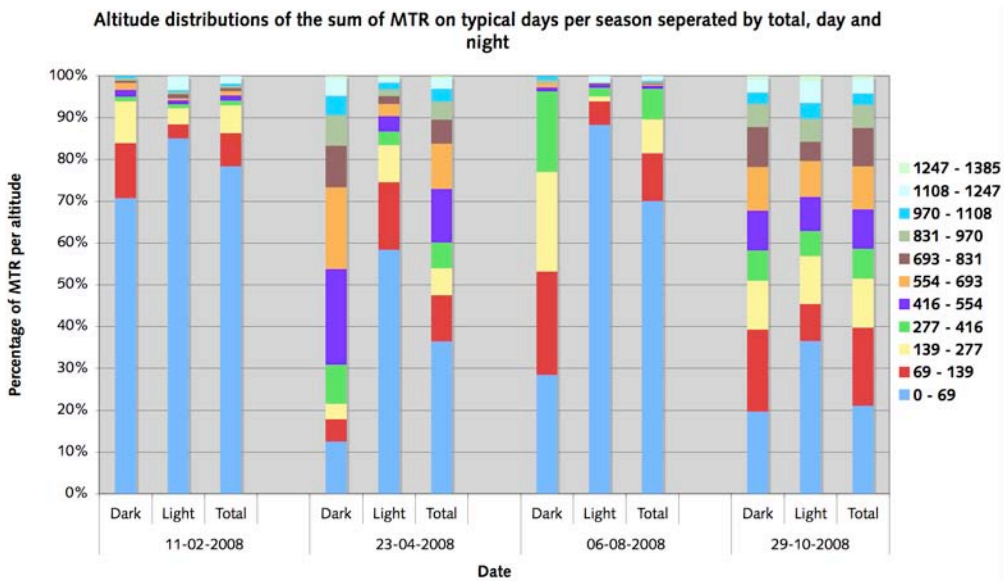


Figure 6.3 Altitude distribution (fraction of total) of mean fluxes (Mean Traffic Rates) during day, night and total. Data for all altitudes band seperated and averaged over the day, as measured by vertical radar.

In **summer** mainly local flight movements of gulls and cormorants were found (chapter 4). These birds use the wind farm for foraging and roosting throughout the year. They generally fly at lower altitude, similar to results on the typical summer day of the 6th of August 2008 (fig. 6.4). Looking at the vertical radar data most bird groups were in the first studied altitude layer. At night (20:00 – 3:00 GMT) birds tended to exploit higher altitudes but during the day most movements occurred in the lower layers. Cumulatively, most tracks throughout the day were found at the lowest altitudes (fig. 6.5 – black bars).

As explained in app.III.1.2 variability in figures in the NW and SE column are due to the position of birds (heads- on or tails-on). The position is caused by the flight direction of the bird. Thus differences in numbers of bird tracks between columns might give an indication for flight direction of the recorded birds. On this summer day numbers for both columns were similar, except for altitudes in between 139 and 416 m in which slightly more birds were detected in the northwest column. This might indicate that birds at that altitude have a more southerly and easterly flight direction although differences are not profound (fig. 6.5 – grey and white bars).

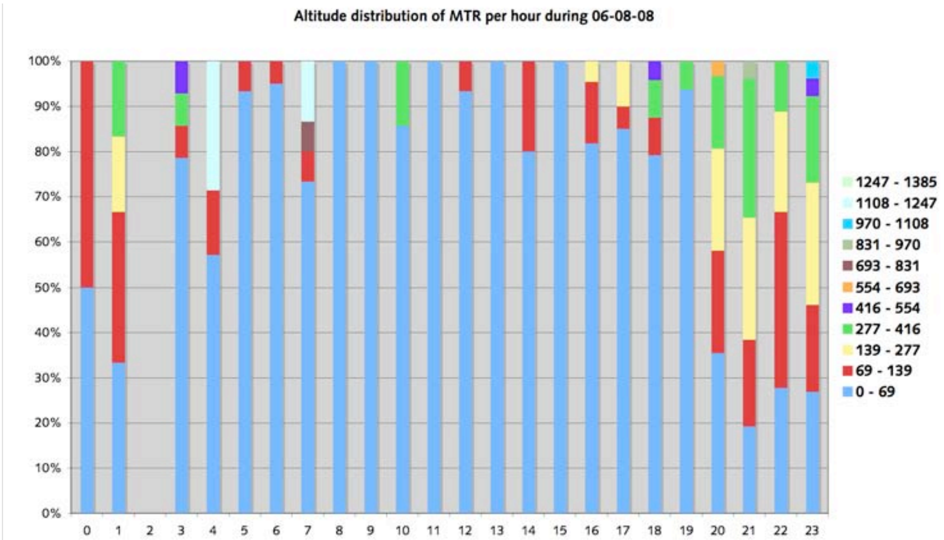


Figure 6.4 Altitude distribution (fraction of total) of mean fluxes (MTR) during the 6th of August 2008. Data are seperated for 11 altitude bands.

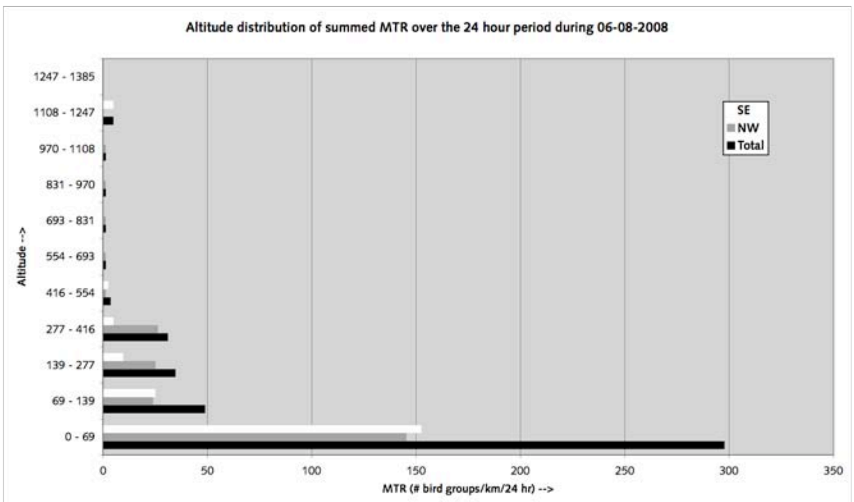


Figure 6.5 Summed fluxes during the 6th of August 2008, separated for different altitude classes and different detection columns.

In **winter** mainly local flight movements of gulls and cormorants were observed in and around the OWEZ wind farm (chapter 4). On a typical winter day like the 11th of February 2008 this pattern was found as well (fig. 6.6). Some more geese and ducks were present in the area but other than that patterns were highly similar to the summer period. Most tracks were found in the lower altitude layers (fig. 6.7 – black bars).

Some differences in flight activity in both columns were detected although it occurred at altitudes between sea level and 139 m. In the northwest column higher flight movements were observed indicating more flight directions from the north and west (fig. 6.7 – grey and white bars).

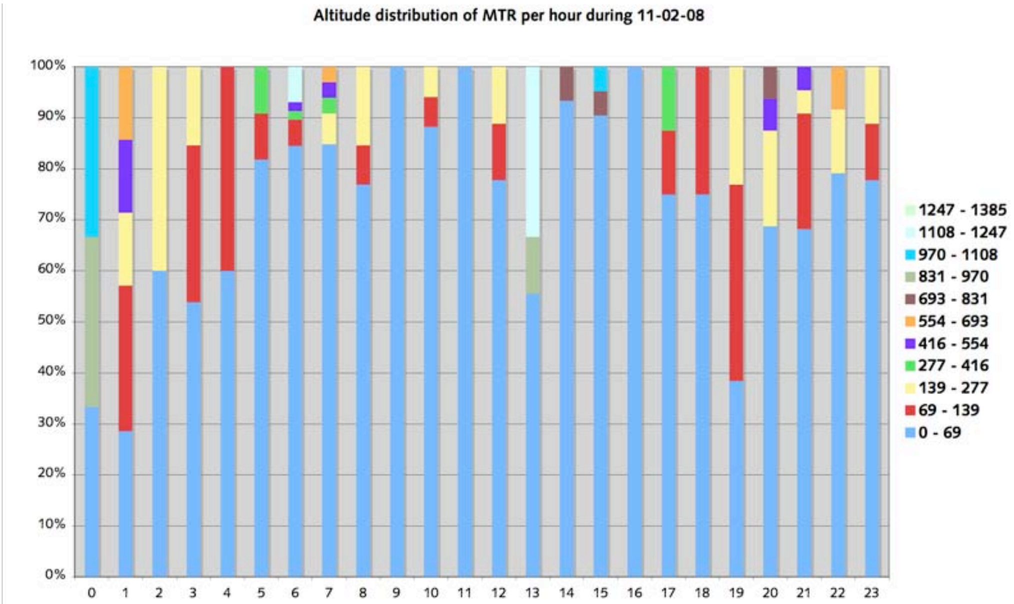


Figure 6.6 Altitude distribution (fraction of total) of mean fluxes (MTR) during the 11th of February 2008. Data are separated in 11 altitude bands.

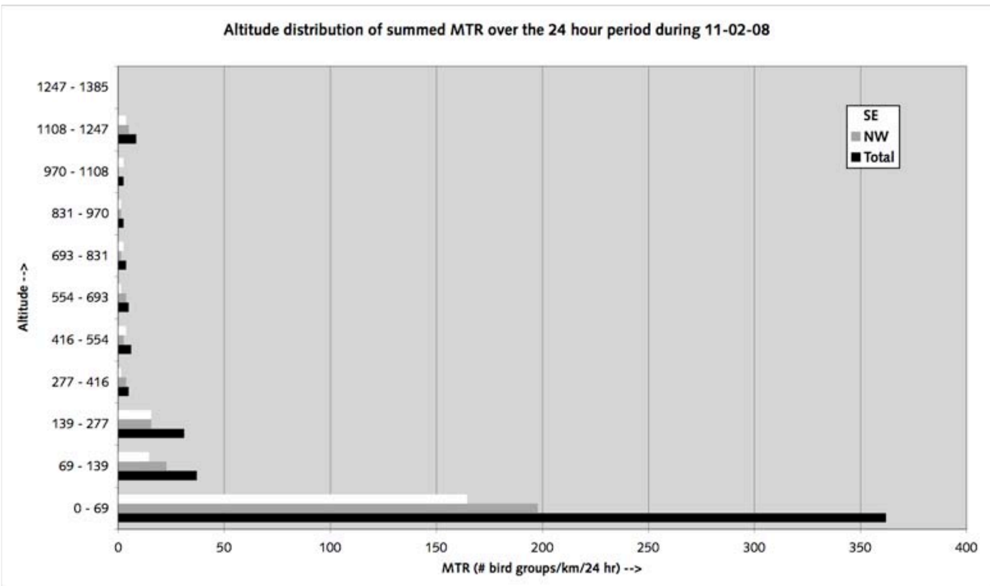


Figure 6.7 Summed fluxes during the 11th of February 2008, separated for different altitude classes and different detection columns.

A typical **spring** migration day/night was the 23rd tot the 24th of April 2008 in which large groups of little gulls were present during the day and migration intensity of thrushes and other songbirds started to increase heavily after 0:00 GMT. This was a night with mainly high altitude movement of probably thrushes. Proportion of high altitude movement (> 416 m) was high during the night (fig. 6.8). In the morning more lower altitude movements occurred. Compared to summer and winter much more high altitude movement occurred (fig. 6.9 – black bars).

No clear differences were found between the two columns. This indicates that directions of flight altitude were straight into the beams from southwest to north east. At some altitudes slightly more bird movements were found in the northwest-column, indicating birds coming from the west (probably the UK) (fig. 6.9 – grey and white bars).

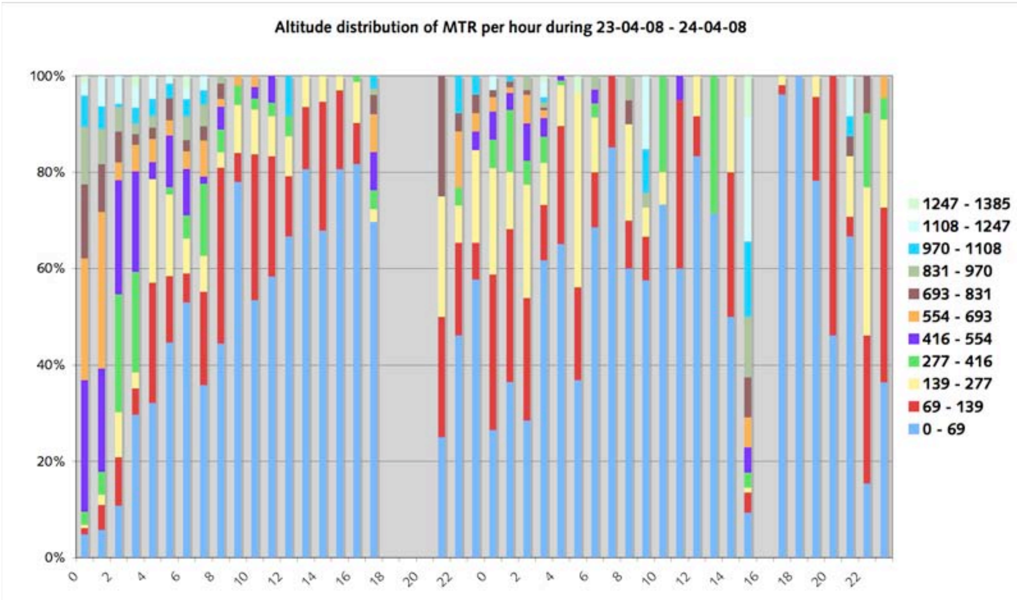


Figure 6.8 Altitude distribution (fraction of total) and mean fluxes (MTR) on the 23rd & 24th of April 2008. Data are separated into 11 altitude bands.

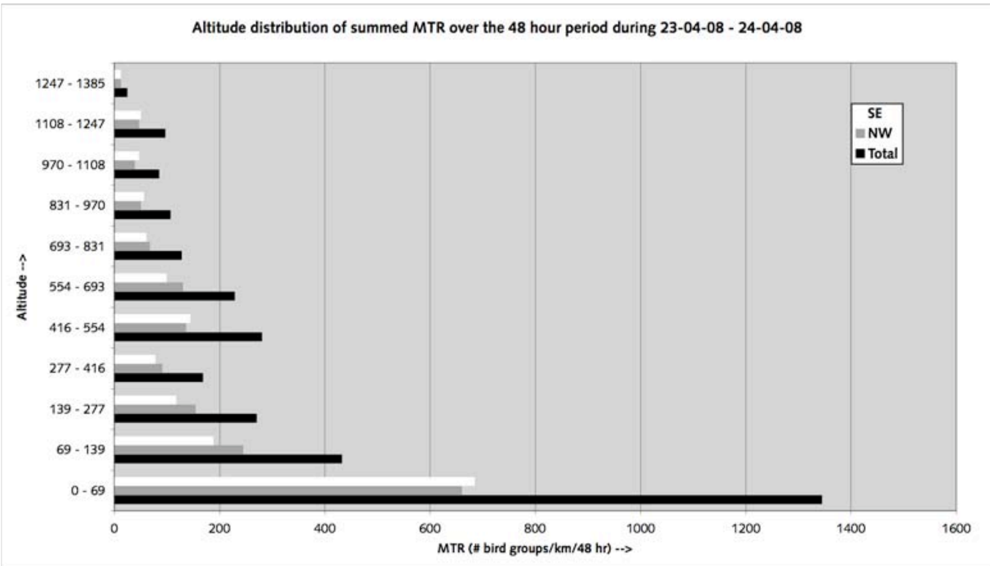


Figure 6.9 Summed fluxes on the 23rd and 24th of April 2008, separated for different altitude classes and different detection columns.

The expected peak in bird numbers during the **autumn** migration period originates from birds coming from north-easterly directions (Scandinavia) flying south-west and west to the wintering grounds. During a typical autumn migration day/night (October 29 & 30 2008) high altitude movements were found throughout the day (fig. 6.10) but especially during the night. This pattern was also observed in nocturnal fluxes (§4.1) and nocturnal calls (§4.3). In autumn, highest fluxes were found in the beginning of the night but at that time birds tended to fly at higher altitudes than later in the night. Therefore numbers of calls heard during these nights seem to be more numerous later in the morning, because then they could be heard better. Bird numbers were higher at higher altitudes, probably representing thrushes (fig. 6.11). At altitudes of 500 to 600 m numerous bird tracks were found on the night of the 29th to the 30st of October.

Throughout all altitudes more bird movements were seen in the northwest column. As all altitudes show this pattern it is expected that this difference is due to the flight direction and not because of barrier effects of the wind farm. Birds are detected better when radiated head on in the radar beam compared to being radiated on the tail. Higher numbers of tracks in the NW column indicate movements from the north parallel to the coast. This confirms our findings of migrating thrushes to their southern winter grounds in the night of the 29th of October 2008.

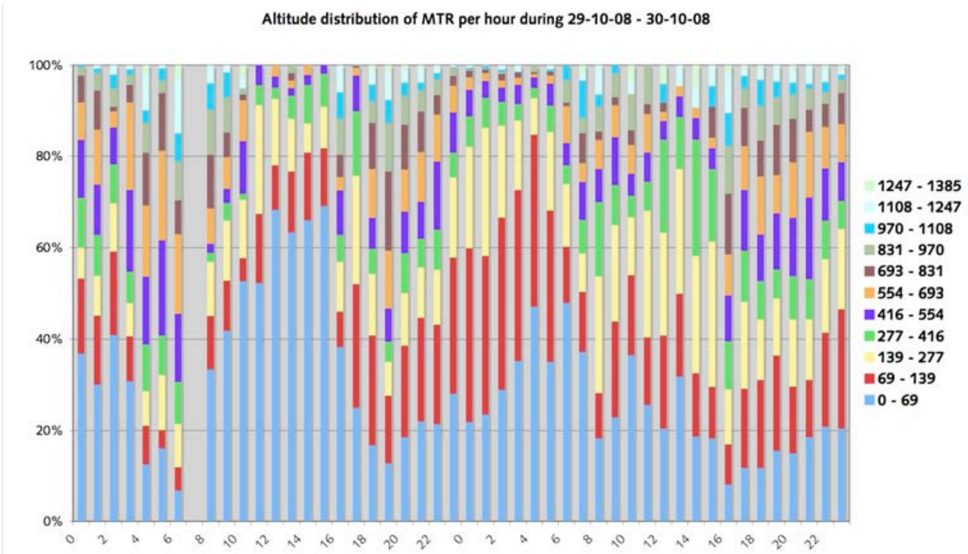


Figure 6.10 Altitude distribution (fraction of total) of mean fluxes (MTR) on the 29th & 30st of October 2008. Data are separated into 11 altitude bands.

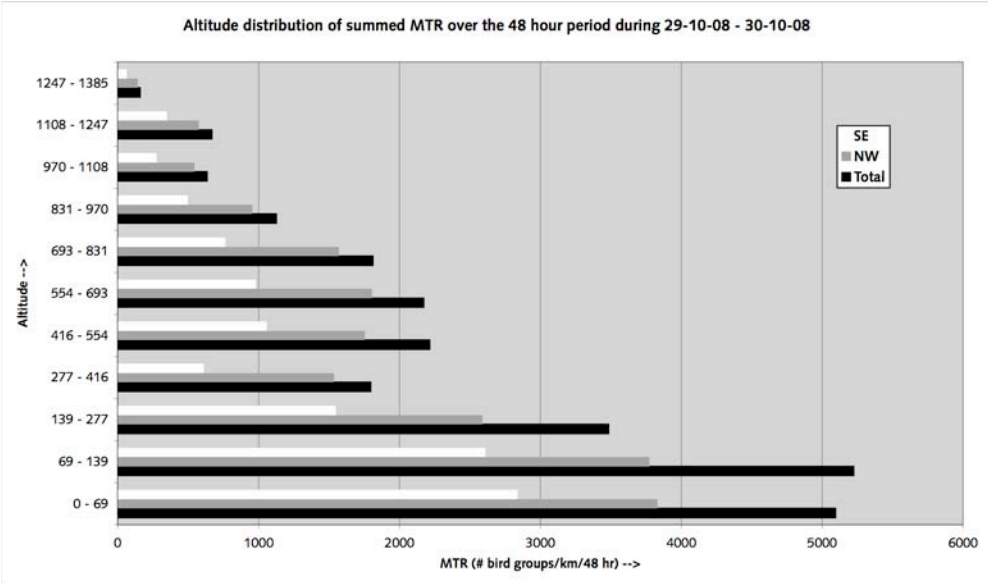


Figure 6.11 Summed fluxes on the 29th and 30st of October 2008, separated for different altitude classes and radar columns.

All summed MTR distribution graphs in the past chapter (figs. 6.5, 6.7, 6.9 & 6.11) take not into account that birds at higher altitudes can be missed due to detection problems at high altitudes. Therefore figures at higher altitudes tend to be underestimated in these analyses.

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

6.2 Species-specific patterns (from visual observations)

Dominance of gulls

Flight altitudes of birds were highly variable, depending on weather circumstances and behavioural activities, and also differed highly between species. The mean altitudes varied from 10 up to 50 m (fig. 6.12). Because large gulls were by far the most common species, the overall pattern is highly dominated by these species. For most species, flight altitudes were on average comparable to flight altitudes measured in the baseline situation.

Altitudes inside versus outside the wind farm

Birds tended to fly higher within the wind farm (fig. 6.12). The difference was most evident for large gulls. The opposite pattern was shown for terns, which had lower flight altitudes near or in the farm than further away from it. This is probably due to a relative high proportion of foraging terns within the wind farm.

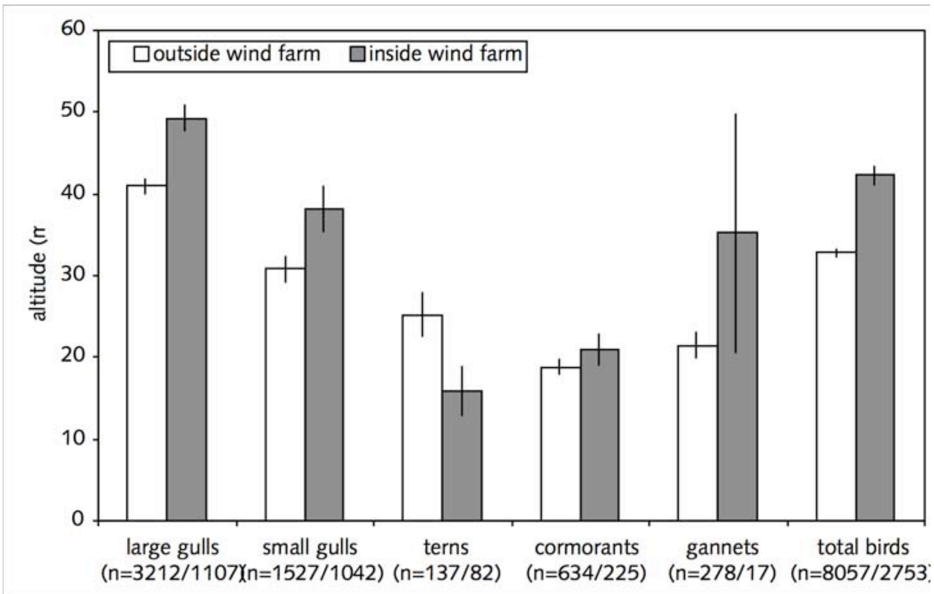


Figure 6.12 Flight altitude (mean with standard error) inside and outside the wind farm, as observed in the panorama scans. The number of birds is given in brackets (outside/inside).

Changes in altitudes observed from flight paths

Visual observations on flight paths of individual birds yield additional information on changes in flight altitudes when birds enter or leave the wind farm. The altitudes of larger gulls were generally similar inside and outside of the wind farm (fig 6.13). Small gulls were recorded at higher altitudes inside the wind farm, while terns, cormorants and gannets were recorded at higher altitudes outside the wind farm. For all birds combined, flight altitudes were higher inside the wind farm than outside. Except for cormorants and gannets, these patterns generally reflect those recorded during panorama scans (see fig. 6.12).

For 55 bird groups we could record flight altitudes both within and outside of the wind farm, when these groups entered or left the wind farm. The mean flight altitudes inside and outside of the wind farm varied between species (fig. 6.14). A total of 22 species groups showed a higher mean flight altitude inside the wind farm than outside, 14 showed no difference and 19 showed a lower mean flight altitude inside the wind farm than outside. Overall flight altitude was significantly lower outside the wind farm (paired t-test: T_{54}=2,85, $p<0.01$; inside 54m avg, outside 37m avg). The greatest difference between flight altitudes inside and outside of the wind farm was of guillemot, which showed an increase in mean flight height of 190 m inside the wind farm compared to outside the wind farm. The greatest decrease in altitude inside the wind farm was shown by barnacle goose and was 50 m lower inside the wind farm than outside.

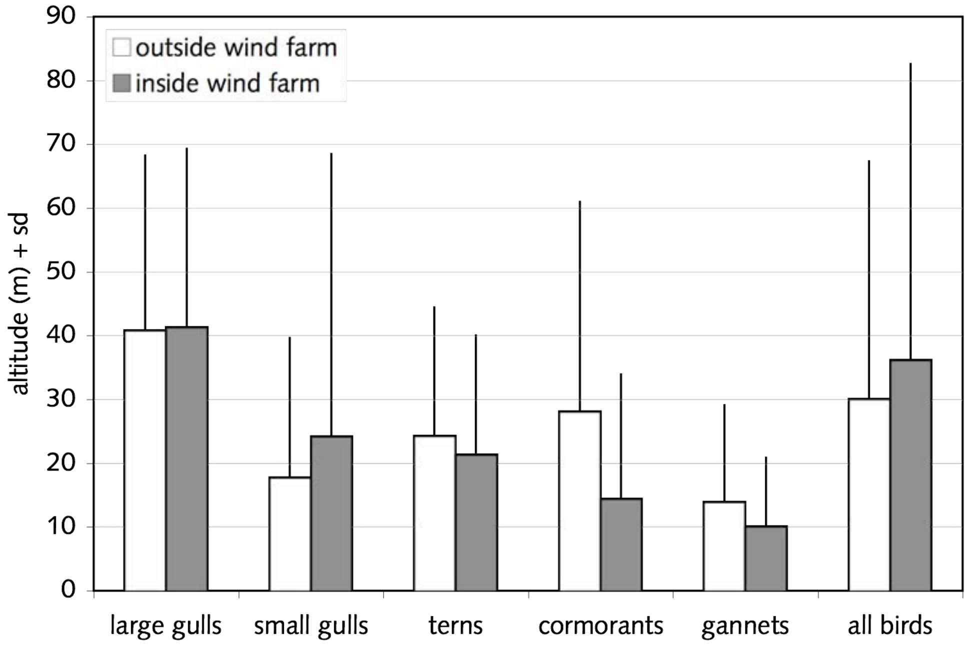


Figure 6.13 Mean flight altitudes outside and inside the wind farm, as observed through visual observations.

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

7 Discussion and conclusions

Scope of this progress report

In this progress report, preliminary results are presented on data obtained after nearly two years of study 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, and whether methods that are used provide the required data or need to be adjusted.

Conclusions presented in the report at hand are preliminary and may change when more data are collected and analysed during the remainder of the study period. Observations continue through most of 2009, and final analysis and 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 (2010).

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 main 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), flight altitudes of birds (§7.4) and future work (§7.5).

7.1 Radar performance

Conclusions

Vertical radar

- The vertical X-band radar has performed well, with virtually no breakdowns despite frequent harsh weather conditions. This positive result is due to a different hardware construction compared to the baseline study, and to the fact that the radar can be switched off remotely when winds exceed 7 Bft.
- The detection tests that were carried out, indicated that Merlin tracked most bird movements through the radar beam. On average, 95% of visually counted bird tracks on the Furuno raw radar screen were recorded by Merlin.
- In continuation of the first interim report, a model was developed to remove clutter recorded from the vertical radar. Clutter tracks could be removed to a large extent by filtering out those areas where clutter was most created (turbines, area ca. 200 m around the radar). Clutter was additionally removed based on echo characteristics, most prominent of which were tracklength and deviation in heading, speed and altitude. Further development of the model, which is scheduled for 2009 is needed to further improve the clutter filter.

Horizontal radar

- The horizontal S-band radar has performed equally well as the vertical radar. Only a few technical problems were encountered.
- Merlin tracked birds flying in the area well 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. As a result, windy days will be less fit to use for flight path analysis. A threshold level of clutter-level will be set, above which data will not be analysed. The effects of weather conditions are 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.
- Detection effects were visible on days with abundant song bird migration. The range with which these small birds were detected was smaller than the detection range of gulls. This aspect will be treated with care in the final analysis, as it is relevant in determining the occurrence of deflection behaviour of smallest species. Detection of larger birds (thrush-size and up) extended to nearly the full range of the radar.
- A subset of the data in which birds and clutter were identified as such was collected during the study period up to 31st December 2008. As expected, this dataset proves to be a useful tool to separate birds from clutter. Preliminary analysis of this dataset indicates that tracks of birds and clutter vary largely in both tracklength and trackquality. Overall, these preliminary results suggest that bird tracks can be separated from clutter tracks sufficiently well to reveal patterns in flight paths such as deflection. This aspect will be analysed in further detail and presented in the final report.

7.2 Fluxes

- The vertical radar system has been collecting data on flight intensity of birds from April 2007 through December 2008, the end of the reported study period. In addition, visual observations carried out in the same period yield species-specific information on flight intensities and support the radar results.
- Fluxes were low, with 5-20 bird groups/km/h on average measured by radar, similar to results reported in the first progress report. Visual observations confirm this pattern. Fluxes were considerably lower than measured in the baseline study (Krijgsveld *et al.* 2005). This is in part related to the location of the wind farm on the Dutch shelf (Leopold & Camphuysen 2008), and in part to the significantly lower numbers of fishing vessels in the effect study compared to the baseline study.
- Gulls were by far the most common species that were observed in the wind farm area.
- Measurements during migration in the spring of 2008 reveal a moderate increase in fluxes, which is much lower than the peak measured during autumn migration. This is possibly an effect of birds having reached higher altitudes by

the time they arrive at the wind farm location, and therewith flying above the range of detection of the radar.

- Fluxes measured on peak migration nights in autumn were as high as 2600 bird groups/km/h. This is on the low end of migration rates on land.
- In summer, flight activity measured with radar was not much lower than during other seasons, and almost similar to winter activity. Visual observations however resulted in lowest bird numbers in this season. Further analysis and calibration of the data will be done to evaluate whether these fluxes reflect actual bird activity, or whether they include 'clutter' such as insects. A way to approach this is to relate flight speed and direction to wind speed and direction. In summer, flight activity of birds is expected to be more or less random as a result of foraging behaviour of local breeding birds and in absence of migratory activity. Additionally, flight paths recorded with the horizontal radar will be compared to these observations.
- Fluxes at night exceeded those at daytime during autumn and spring migration, and were lower than at daytime in winter and summer. This is consistent with expectations.
- In autumn, highest fluxes were recorded in the early night, while in spring highest fluxes were recorded later in the night, both by radar and visually/acoustically. This is consistent with birds leaving the Dutch coast at dusk in the fall, and arriving at the near-shore wind farm shortly afterwards, and with birds in spring having to fly further before they reach the wind farm location and thus arriving later in the night.
- Visual observations showed a lower bird density within the wind farm than outside it. Of birds of the most abundant species flying in the area, only 30% was encountered within the wind farm. This indicates avoidance, which is remarkable given that these numbers concern species that did not show deflection in their flight paths.

7.3 Flight paths

- Preliminary results indicate that deflection occurred during day in most species flying in the wind farm area. The distance from the wind farm at which deflection occurs varies from 200 m up to ca. 2 NM. At night, first results indicate that birds tend to deflect much less. This can be either because birds are flying at higher altitudes at night, and pass over the wind farm, or because birds don't register the presence of the wind farm as much during dark. These patterns will be analysed in further detail in the coming study period, when the flight paths recorded by horizontal radar become available.
- Gulls, cormorants and terns did not show much avoidance and were seen foraging in the wind farm on a regular basis.
- Seabirds such as gannets, scoters, auks and guillemots and divers showed a strong avoidance of the wind farm. Gannets changed their flight direction away from the wind farm at relatively close distances (down to 500 m). They occasionally ventured into the wind farm briefly, during foraging flights. The other seabird species generally passed at much larger distances (>2-4 km). Very few individuals were recorded near or within the wind farm. Abundance of

seabirds other than gannets was low in the broad area around the wind farm (see Leopold & Camphuysen 2008), so present results are based on limited observations.

- Migrating landbirds in part did and in part did not show strong avoidance. Geese flying at rotor height showed strongest reactions to the turbines, often with panic behaviour (at 0.5-1 km from the wind farm, then flying around the entire wind farm). When flying above rotor height, no avoidance was recorded in any species. Passerines, that probably constitute the majority of the birds migrating through the area, generally showed deflection around the entire wind farm. Individually observed birds generally flew alongside the wind farm boundaries for a while, and eventually entered the wind farm to continue on their original flight route.
- Often birds other than gulls and cormorants entered the wind farm at a turbine that was standing still. Gulls, cormorants and terns as well entered the wind farm anywhere.
- Data obtained in the accompanying study on local birds in the wind farm area and surroundings (see Leopold & Camphuysen 2008), will give insight in distribution patterns of the various bird species in a larger area around the wind farm. Presence and absence of flight activity will be further interpreted using insights from this study (final report 2010).

7.4 Flight altitudes

- Flight altitude patterns were generally in line with results found in the baseline study (Krijgsveld *et al.* 2005).
- Most flight activity was recorded in the lowest altitude bands (up to 70 m), especially during winter when bird activity comprised mainly local seabirds.
- Flight activity was highest during autumn and in the night at high altitudes. In summer most activity was found at lower altitudes.
- Migrating passerines flew both at very low altitudes (concentrated at less than 300 m) and at a wide range of altitudes up to the highest altitude measured (1500 m). The altitude pattern is likely to be related to wind directions, this will be assessed and reported in the final report (2010).
- Flight activity was recorded at all altitudes throughout the year.
- In general, flight altitudes were higher inside the wind farm than outside of it. This appears to be a result of avoidance (in vertical direction). This is because when we look at flight paths of individual birds, as opposed to average altitudes of all birds in the area, birds significantly lowered their flight altitude.

7.5 Future work

In order to obtain further information on flight paths of birds, the following observations will be carried out in 2009:

- **Flight patterns of birds in winter**. The abundance of local seabirds such as scoters, divers, auks and guillemots is very low in the area of the OWEZ wind farm. On top of that, their presence in the area is limited to the winter months.

These species however are of high concern in respect to conservation. In addition, current results indicate that they show a strong response to the presence of the wind farm. Because of this, observations will continue in the first months of 2009. These data should provide the necessary increase in sample size to be able to assess the effects of the wind farm on this species group.

- **Flight patterns of birds in spring.** Observations began in the spring of 2007. Because the radar system was at that point still in its testing phase, data recorded at that time were very limited. Visual observations started effectively when the migration season was nearly over. Because of this, observations will continue through the spring of 2009. At this time, additional nocturnal observations are planned as well, to gain further insight in the species spectrum present in the area at night. Data on this subject are difficult to obtain due to the difficult and unsafe observation conditions offshore.
- **Species composition at night.** Acoustic data have been recorded at the metmast during migration. To determine which species were heard flying over the metmast during migration, the University of Leiden and Bureau Waardenburg are developing a system to analyse these data. Results will be presented in the final report (2010).
- **Distance at which avoidance occurs**. Flight paths of birds migrating south in autumn are limited to the actual wind farm area, because the radars are positioned south of the wind farm. To gain insight in occurrence and distance of avoidance in birds approaching from the NE, a radar from the Vessel Traffic Control is used to record these flight paths. Because this radar is of the X-band type, it is more sensitive to sea clutter. As a result, measurements can only be used on very calm days, and observations will be limited to larger species. From other directions, distance at which avoidance occurs can be assessed with the Merlin radar at the metmast (final report 2010).
- **Flight behaviour close to turbines.** How birds respond behaviourally to an individual wind turbine determines to a large extent what the risk is of the bird colliding with that turbine. In order to calculate collision rates, our measurement of fluxes will be combined with measurements of avoidance behaviour. For this purpose, observations in the summer of 2009 will focus on behaviour of birds that are flying close to turbines. The radar settings will be changed to maximise detection of tracks close to a selection of turbines. Visual observations will similarly concentrate on species-specific flight paths close to these turbines.

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Appendix I Species names

Translations of species names in Latin and Dutch. List is not limited to species seen in the wind farm area.

English name	Name	Dutch name
Mute Swan	*Cygnus olor*	knobbelzwaan
Bewick's Swan	*Cygnus bewickii*	kleine zwaan
Whooper Swan	*Cygnus cygnus*	wilde zwaan
Taiga Bean Goose	*Anser fabalis*	taigarietgans
Tundra Bean Goose	*Anser serrirostris*	toendrarietgans
Pink-footed Goose	*Anser brachyrhynchus*	kleine rietgans
Greylag Goose	*Anser anser*	grauwe gans
Greater White-fronted Goose	*Anser albifrons*	kolgans
Cackling Goose	*Branta hutchinsii*	kleine canadese gans
Canada Goose	*Branta canadensis*	grote canadese gans
Barnacle Goose	*Branta leucopsis*	brandgans
Pale-bellied Brent Goose	*Branta hrota*	witbuikrotgans
Dark-bellied Brent Goose	*Branta bernicla*	rotgans
Black Brant	*Branta nigricans*	zwarte rotgans
Egyptian Goose	*Alopochen aegyptiaca*	nijlgans
Common Shelduck	*Tadorna tadorna*	bergeend
Common Pochard	*Aythya ferina*	tafeleend
Tufted Duck	*Aythya fuligula*	kuifeend
Greater Scaup	*Aythya marila*	topper
Common Eider	*Somateria mollissima*	eider
Black Scoter	*Melanitta nigra*	zwarte zee-eend
Velvet Scoter	*Melanitta fusca*	grote zee-eend
Long-tailed Duck	*Clangula hyemalis*	ijseend
Smew	*Mergellus albellus*	nonnetje
Common Goldeneye	*Bucephala clangula*	brilduiker
Goosander	*Mergus merganser*	grote zaagbek
Red-breasted Merganser	*Mergus serrator*	middelste zaagbek
Gadwall	*Anas strepera*	krakeend
Eurasian Wigeon	*Anas penelope*	smient
Northern Shoveler	*Anas clypeata*	slobeend
Mallard	*Anas platyrhynchos*	wilde eend
Northern Pintail	*Anas acuta*	pijlstaart
Garganey	*Anas querquedula*	zomertaling
Common Teal	*Anas crecca*	wintertaling
Red-throated Loon	*Gavia stellata*	roodkeelduiker
Black-throated Loon	*Gavia arctica*	parelduiker
Great Northern Loon	*Gavia immer*	ijsduiker
Yellow-billed Loon	*Gavia adamsii*	geelsnavelduiker
Northern Fulmar	*Fulmarus glacialis*	noordse stormvogel
Sooty Shearwater	*Puffinus griseus*	grauwe pijlstormvogel
Manx Shearwater	*Puffinus puffinus*	noordse pijlstormvogel
Balearic Shearwater	*Puffinus mauretanicus*	vale pijlstormvogel
European Storm Petrel	*Hydrobates pelagicus*	stormvogeltje
Leach's Storm Petrel	*Oceanodroma leucorhoa*	vaal stormvogeltje
Northern Gannet	*Morus bassanus*	Jan-van-gent
Great Cormorant	*Phalacrocorax carbo*	aalscholver
European Shag	*Phalacrocorax aristotelis*	kuifaalscholver
Little Egret	*Egretta garzetta*	kleine zilverreiger
Great Egret	*Casmerodius albus*	grote zilverreiger
Grey Heron	*Ardea cinerea*	blauwe reiger
Purple Heron	*Ardea purpurea*	purperreiger
White Stork	*Ciconia ciconia*	ooievaar
Eurasian Spoonbill	*Platalea leucorodia*	lepelaar
Little Grebe	*Tachybaptus ruficollis*	dodaars
Great Crested Grebe	*Podiceps cristatus*	fuut
Red-necked Grebe	*Podiceps grisegena*	roodhalsfuut
Horned Grebe	*Podiceps auritus*	kuifduiker
Black-necked Grebe	*Podiceps nigricollis*	geoorde fuut
Western Marsh Harrier	*Circus aeruginosus*	bruine kiekendief

Northern Harrier	*Circus cyaneus*	blauwe kiekendief
Montagu's Harrier	*Circus pygargus*	grauwe kiekendief
Northern Goshawk	*Accipiter gentilis*	havik
Eurasian Sparrowhawk	*Accipiter nisus*	sperwer
Common Buzzard	*Buteo buteo*	buizerd
Osprey	*Pandion haliaetus*	visarend
Common Kestrel	*Falco tinnunculus*	torenvalk
Red-footed Falcon	*Falco vespertinus*	roodpootvalk
Merlin	*Falco columbarius*	smelleken
Eurasian Hobby	*Falco subbuteo*	boomvalk
Peregrine Falcon	*Falco peregrinus*	slechtvalk
Eurasian Coot	*Fulica atra*	meerkoet
Eurasian Oystercatcher	*Haematopus ostralegus*	scholekster
Pied Avocet	*Recurvirostra avosetta*	kluut
Little Ringed Plover	*Charadrius dubius*	kleine plevier
Common Ringed Plover	*Charadrius hiaticula*	bontbekplevier
Kentish Plover	*Charadrius alexandrinus*	strandplevier
Eurasian Dotterel	*Charadrius morinellus*	morinelplevier
European Golden Plover	*Pluvialis apricaria*	goudplevier
Grey Plover	*Pluvialis squatarola*	zilverplevier
Northern Lapwing	*Vanellus vanellus*	kievit
Red Knot	*Calidris canutus*	kanoet
Sanderling	*Calidris alba*	drieteenstrandloper
Little Stint	*Calidris minuta*	kleine strandloper
Curlew Sandpiper	*Calidris ferruginea*	krombekstrandloper
Purple Sandpiper	*Calidris maritima*	paarse strandloper
Dunlin	*Calidris alpina*	bonte strandloper
Ruff	*Philomachus pugnax*	kemphaan
Common Snipe	*Gallinago gallinago*	watersnip
Eurasian Woodcock	*Scolopax rusticola*	houtsnip
Black-tailed Godwit	*Limosa limosa*	grutto
Bar-tailed Godwit	*Limosa lapponica*	rosse grutto
Eurasian Whimbrel	*Numenius phaeopus*	regenwulp
Eurasian Curlew	*Numenius arquata*	wulp
Common Sandpiper	*Actitis hypoleucos*	oeverloper
Green Sandpiper	*Tringa ochropus*	witgat
Spotted Redshank	*Tringa erythropus*	zwarte ruiter
Common Greenshank	*Tringa nebularia*	groenpootruiter
Wood Sandpiper	*Tringa glareola*	bosruiter
Common Redshank	*Tringa totanus*	tureluur
Ruddy Turnstone	*Arenaria interpres*	steenloper
Wilson's Phalarope	*Phalaropus tricolor*	grote franjepoot
Red-necked Phalarope	*Phalaropus lobatus*	grauwe franjepoot
Red Phalarope	*Phalaropus fulicaria*	rosse franjepoot
Pomarine Skua	*Stercorarius pomarinus*	middelste jager
Parasitic Jaeger	*Stercorarius parasiticus*	kleine jager
Long-tailed Jaeger	*Stercorarius longicaudus*	kleinste jager
Great Skua	*Stercorarius skua*	grote jager
Sabine's Gull	*Xema sabini*	vorkstaartmeeuw
Black-legged Kittiwake	*Rissa tridactyla*	drieteenmeeuw
Common Black-headed Gull	*Chroicocephalus ridibundus*	kokmeeuw
Little Gull	*Hydrocoleus minutus*	dwergmeeuw
Mediterranean Gull	*Larus melanocephalus*	zwartkopmeeuw
Great Black-headed Gull	*Larus ichthyaetus*	reuzenzwartkopmeeuw
Mew Gull	*Larus canus*	stormmeeuw
Lesser Black-backed Gull	*Larus fuscus*	kleine mantelmeeuw
European Herring Gull	*Larus argentatus*	zilvermeeuw
Yellow-legged Gull	*Larus michahellis*	geelpootmeeuw
Caspian Gull	*Larus cachinnans*	pontische meeuw
Iceland Gull	*Larus glaucoides*	kleine burgemeester
Glaucous Gull	*Larus hyperboreus*	grote burgemeester
Great Black-backed Gull	*Larus marinus*	grote mantelmeeuw
Little Tern	*Sternula albifrons*	dwergstern
Caspian Tern	*Hydroprogne caspia*	reuzenstern
Sandwich Tern	*Sterna sandvicensis*	grote stern

Common Tern	*Sterna hirundo*	visdief
Arctic Tern	*Sterna paradisaea*	noordse stern
Atlantic Murre	*Uria aalge*	zeekoet
Razorbill	*Alca torda*	alk
Black Guillemot	*Cepphus grylle*	zwarte zeekoet
Little Auk	*Alle alle*	kleine alk
Atlantic Puffin	*Fratercula arctica*	papegaaiduiker
Common Pigeon	*Columba livia*	rotsduif
Stock Dove	*Columba oenas*	holenduif
Common Wood Pigeon	*Columba palumbus*	houtduif
Eurasian Collared Dove	*Streptopelia decaocto*	turkse tortel
European Turtle Dove	*Streptopelia turtur*	zomertortel
Short-eared Owl	*Asio flammeus*	velduil
Common Swift	*Apus apus*	gierzwaluw
Eurasian Skylark	*Alauda arvensis*	veldleeuwerik
Sand Martin	*Riparia riparia*	oeverzwaluw
Barn Swallow	*Hirundo rustica*	boerenzwaluw
Common House Martin	*Delichon urbicum*	huiszwaluw
Tree Pipit	*Anthus trivialis*	boompieper
Meadow Pipit	*Anthus pratensis*	graspieper
Eurasian Rock Pipit	*Anthus petrosus*	oeverpieper
Water Pipit	*Anthus spinoletta*	waterpieper
Blue-headed Wagtail	*Motacilla flava*	gele kwikstaart
Grey Wagtail	*Motacilla cinerea*	grote gele kwikstaart
White Wagtail	*Motacilla alba*	witte kwikstaart
Pied Wagtail	*Motacilla yarrellii*	rouwkwikstaart
Bohemian Waxwing	*Bombycilla garrulus*	pestvogel
Winter Wren	*Troglodytes troglodytes*	winterkoning
Dunnock	*Prunella modularis*	heggenmus
European Robin	*Erithacus rubecula*	roodborst
Common Nightingale	*Luscinia megarhynchos*	nachtegaal
Black Redstart	*Phoenicurus ochruros*	zwarte roodstaart
Common Redstart	*Phoenicurus phoenicurus*	gekraagde roodstaart
Whinchat	*Saxicola rubetra*	paapje
European Stonechat	*Saxicola rubicola*	roodborsttapuit
Northern Wheatear	*Oenanthe oenanthe*	tapuit
Ring Ouzel	*Turdus torquatus*	beflijster
Common Blackbird	*Turdus merula*	merel
Fieldfare	*Turdus pilaris*	kramsvogel
Song Thrush	*Turdus philomelos*	zanglijster
Redwing	*Turdus iliacus*	koperwiek
Mistle Thrush	*Turdus viscivorus*	grote lijster
Common Whitethroat	*Sylvia communis*	grasmus
Garden Warbler	*Sylvia borin*	tuinfluiter
Eurasian Blackcap	*Sylvia atricapilla*	zwartkop
Common Chiffchaff	*Phylloscopus collybita*	tjiftjaf
Willow Warbler	*Phylloscopus trochilus*	fitis
Goldcrest	*Regulus regulus*	goudhaan
Firecrest	*Regulus ignicapilla*	vuurgoudhaan
Spotted Flycatcher	*Muscicapa striata*	grauwe vliegenvanger
European Pied Flycatcher	*Ficedula hypoleuca*	bonte vliegenvanger
Bearded Reedling	*Panurus biarmicus*	baardman
Western Jackdaw	*Corvus monedula*	kauw
Rook	*Corvus frugilegus*	roek
Carrion Crow	*Corvus corone*	zwarte kraai
Hooded Crow	*Corvus cornix*	bonte kraai
Common Starling	*Sturnus vulgaris*	spreeuw
House Sparrow	*Passer domesticus*	huismus
Common Chaffinch	*Fringilla coelebs*	vink
Brambling	*Fringilla montifringilla*	keep
European Greenfinch	*Chloris chloris*	groenling
European Goldfinch	*Carduelis carduelis*	putter
Eurasian Siskin	*Carduelis spinus*	sijs
Common Linnet	*Carduelis cannabina*	kneu
Mealy Redpoll	*Carduelis flammea*	grote barmsijs
Snow Bunting	*Plectrophenax nivalis*	sneeuwgors
Common Reed Bunting	*Emberiza schoeniclus*	rietgors

Appendix II List of Merlin echo characteristics

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	Consistency with which a track is recorded by Merlin. Higher value indicates the object was missed more often in the previous scans, lower value indicates the object was seen in up to all previous scans.
Track distance		Distance from the current location to the furthest point used to correlate the track (C or D) in units defined by SPEED UNITS field in Metadata table. Units Knots or MPH = Feet and KPH = Meters
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

S-band Data	X-band Data	Definitions
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
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
	Cross Track Ft	Distance in feet along the surface of the water or ground that a target is away from the radar

Appendix III Radar performance & data handling

In this appendix we present those data that were collected in order to monitor, validate 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 that was available at the time this project was initiated, 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 discussed below. The analysis will be completed in the coming year of study. The complete outcome of the various validation experiments will be described in the final report of this research programme.

III.1 Vertical radar

III.1.1 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 is still 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.

Flagfile

To determine the characteristics of various bird and non-bird radar echoes, a 'flagfile' was built over the entire fieldwork period; a dataset of echoes recorded by Merlin, which 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 line. 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 of 1438 flags have been assigned during the reported period, on 60 different days (table III.1).

Table III.1 Number of flagged echoes for vertical Merlin data.

group	nr of flagged tracks
bird	811
clutter	522
turbine	79
insect	21
ship	5

Clutter analysis

The dataset consists of bird and non-bird tracks and to be able to distinguish between these different groups, 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 visualised 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 by different methods to be able to remove clutter from the vertical radar database.

CART

As done during the baseline study described in Krijgsveld *et al.* (2005) thresholds can be automatically determined using Classification and Regression Trees. Similarly, CART analysis was used in the current study to separate birds and clutter in the database. CART readily provided what seemed to be a sound set of filtering rules, but after the application of the threshold values proposed by the classification tree, validation with the Merlin data showed that these threshold values resulted in removing too much of the bird tracks from the database (see next §III.1.2). In other words, the threshold values were too 'tight'. This means that probably the flagfile is not a good representative of the actual database that Merlin collected and saved throughout the year. This is probably due to the percentage of tracks from the various clutter types and from birds being different in the flagfile than in the actual database. The causes and consequences of this are unclear and are currently being investigated further. The additional year of fieldwork will make the database and flagfile more robust and we will report more information and solutions in the final report.

Expert judgement

To come up with a new and better clutter removal filter different filtering rules were sought to separate clutter from birds. For this purpose we used biologically and mathematically meaningful differences between bird and clutter data, rather than arbitrary statistical cut-off points. We selected echo characteristics that were bound to differ between birds and clutter, given the 'behaviour' of bird- and clutter tracks. Standard deviations of the heading (clutter has more irregular direction than birds), speed (clutter differs more in speed between echoes than birds), flight altitude (birds have a more or less constant flight altitude) were divided by track length and prove to separate clutter and birds quite well in addition to range, altitude limitations as well as the value of track quality.

Filtering rules

The thresholds of these characteristics were set to such a level that limited 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 (table III.2 and figure III.1):

- sum track type / track length (*i.e.* track quality)
- standard deviation of heading / track length
- standard deviation of speed / track length
- standard deviation of flight altitude (AGLft)/ track length

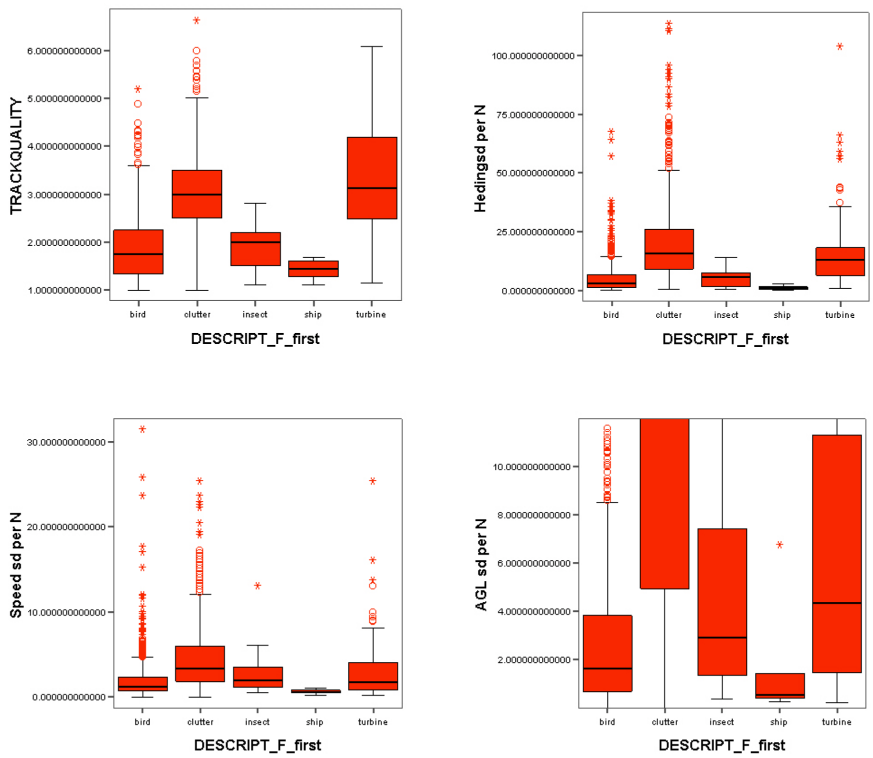


Figure III.1 Boxplots of flagged echo characteristics of vertical Merlin data, used to assign criteria (boundary values) for the distinction between different groups of objects. Box: 50% of data, horizontal line: mean.

Table III.2 Criteria and threshold values for discriminating echo characteristics to remove non-bird tracks from the Merlin database.

echo characteristic	criterium and threshold level
range	tracks at a range < 206 m or > 0,75 NM were removed
tracklength	tracks with a tracklength < 3 hits were removed
turbine position	tracks on turbine positions
trackquality	tracks with a trackquality < 3,6 were removed
heading sd/n	tracks where sd of the heading was > 14 were removed
speed sd/n	tracks where sd of the speed was < 4,5 were removed
altitude sd/n	tracks where sd of flight altitude was < 7,5 were removed

Evaluation of filtering rules

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:

- 63% of records manually identified as bird, fell within bird-criteria (Correct)
- 37% of records manually identified as bird, fell outside bird-criteria (Wrong*)
- 88% of records manually identified as non-bird, fell outside bird-criteria (Correct)
- 12% 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.

The group identified as non-bird but within bird criteria (12% of clutter) 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 10% 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, close proximity to radar). The results obtained so far show that the database is rather clean and reflect flight patterns of birds well. Some erroneous patterns are at this point evident in the database and will be addressed and sorted in the coming study period (see §4.1 and §6.1).

The group identified as bird but outside bird criteria (37%) concerns bird tracks that were erroneously removed. This removal is more serious as it leads to an underestimation of fluxes. Most of the birds (23%) are deleted upon applying the clutter filter. The remaining 7% were deleted because of their close proximity to the radar, where so much clutter is recorded that this area can't be used to assess bird fluxes. A negligible percentage of bird tracks (2%) was removed upon applying the turbine filter (removal of tracks at turbine positions). Bird-echoes with tracklengths less than 3 account for 4% of the incorrect removal. Generally bird tracks consist of 4 echoes or more, and it is therefore questionable whether such short tracks are indeed from birds.

In the coming study period attempts will be made to estimate the percentage of tracks lost in the actual database itself by calibrating Merlin-fluxes with visually recorded data on fluxes. Also, the additional year of data collection will make the database more robust and extends the possibilities for more in dept analyses.

Additional clutter removal
To reduce the amount of clutter present in the database, several other database treatments were 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 back lobe 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 reflect sea clutter and were removed from the data set (altitude < 0 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%.

III.1.2 Data validation

Comparison of tracks recorded by Merlin and visually seen on the Merlin screen
In both methods (CART and Expert Judgement) too many tracks were saved compared to visual counts of tracks seen on the radar. A slightly higher number of tracks saved than visually logged is expected because perpendicular tracks are difficult too judge and log, certainly at busy times but the overestimates found in the last fieldwork period are larger than expected. In general the ExpJud method gave better results than CART but none of the two methods were completely comparable to visual observations. No systematic deviance was found either. On the same day both more and fewer tracks were saved by Merlin compared to the visually logged data. In the coming field season the database of simultaneous logging of visually observed tracks and Merlin database analysis will be expanded to clear the subject of overestimates in the database.

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. This is an improvement for detection probability as it is exactly the direction birds are expected to fly during spring and autumn migration.

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 northwestern and the southeastern sides of the radar separately. On average the ratio between NW and SE was 1.07 ± 0.23 meaning that on average MTR was slightly lower in the NW part of the radar beam (fig. III.2). This skew was mostly due to two months (September 2007 and January 2008) in which fluxes in the NW column were much lower than the SE column. The difference between the SE and NW side was much smaller than in the baseline study, as a result of the more perpendicular angle of the radar to the main flight direction. If the visible difference were 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. Similarly, during the summer months, when locally foraging birds dominate the flight paths, no consistent difference between both sides of the beam would be expected. No such patterns were indeed found.

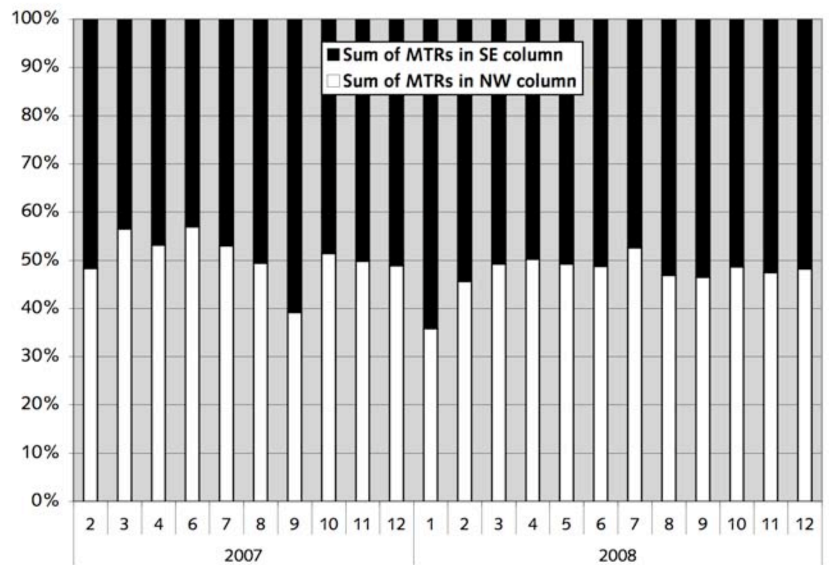


Figure III.2 Heading effects: ratio of Mean Traffic Rate per month in the southeast (black bars) and northwest side of the radar beam (white bars). Data from all altitudes, for day and night combined, as measured by vertical radar.

III.2 Horizontal radar

III.2.1 Data validation 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 to what extent sea clutter was recorded in the database 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 is 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 of the amount of data recorded. Figure III.3 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 was substantially higher. This means that the highest percentage of tracks of birds will be found in data from days with the calmest weather conditions.

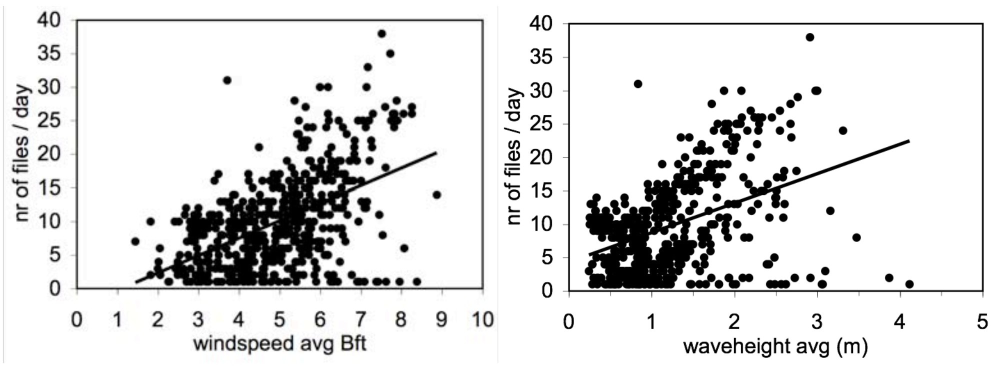


Figure III.3 Relation between number of tracks recorded, visualised as number of files stored per day, and weather conditions.

III.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, a subset of tracks recorded in Merlin was identified visually, similar to the vertical radar data (see §III.1.1 for a more detailed explanation of this process, as well as Krijgsveld *et al.* 2005). A preliminary but promising analysis of these data is presented in this paragraph. Final results will be presented in the final report.

This 'flagging database' consists of 1017 identified echoes (table III.4). Various steps were taken to separate bird – from clutter echoes.

Table III.4 Number of flagged echoes for horizontal Merlin data.

group	nr of flagged echoes
bird	617
clutter	324
rain	8
ship	31
track	37
total	**1017**

Tracklength. The main discriminative feature of bird versus clutter echoes is the length of the track. Sea clutter is inconsistent in movement and direction, and is therefore thought not to generate subsequent echoes of similar characteristics heading in a consequent direction at a consequent speed, while birds consistently flying in the same direction at the same speed should create longer tracks (fig. III.4). Merlin only defines an echo as belonging to the same track when these conditions apply.

Tracklength was in general much larger for bird tracks than for clutter tracks (fig. III.5). However, some overlap occurred. In bird tracks, 20 % of the tracks consisted of less than 5 echoes. In clutter tracks, 8 % of the tracks was longer than 4 echoes (table III.5). Although this percentage is low, it is not sufficient to separate the clutter from the birds. This is because there is such a large amount of clutter in the database that even if only 8% of clutter remains, this will obscure the flight paths of birds. The majority of clutter tracks has a tracklength of 3 or shorter, while the frequency distribution of bird tracks peak at a tracklength of 4 (fig. III.6). A tracklength of 3 and less was on those grounds considered as clutter and excluded from the database. As a result, we remove 87% of clutter and 13% of birds in the flagged database.

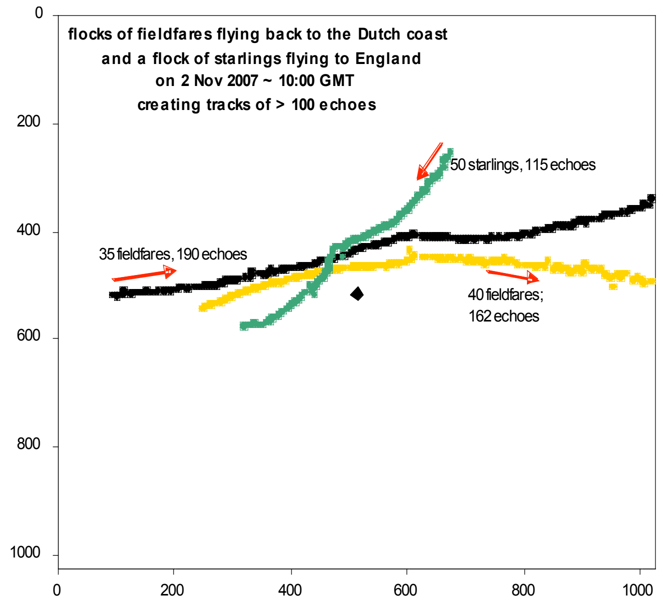


Figure III.4 Examples of long tracks of birds.

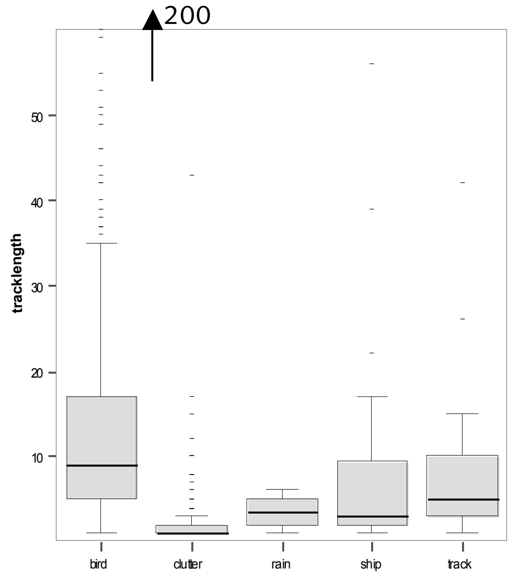
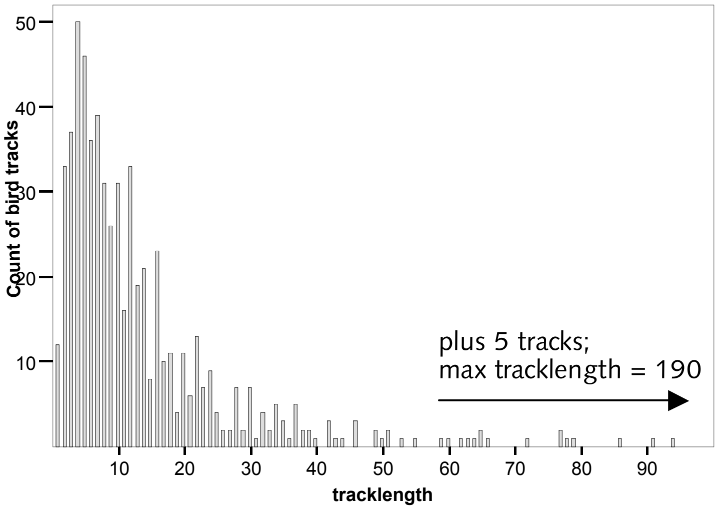


Figure III.5 Variation in tracklengths of various types of radar echoes. Tracklengths of birds were much larger than those of clutter.

Table III.5 Tracklengths of tracks of birds and of clutter.

type	tracklength	n	%
bird	1	12	2
	2	33	5
	3	37	6
	4	50	8
	! 5	485	79
clutter	1	188	58
	2	75	23
	3	17	5
	4	17	5
	! 5	27	8



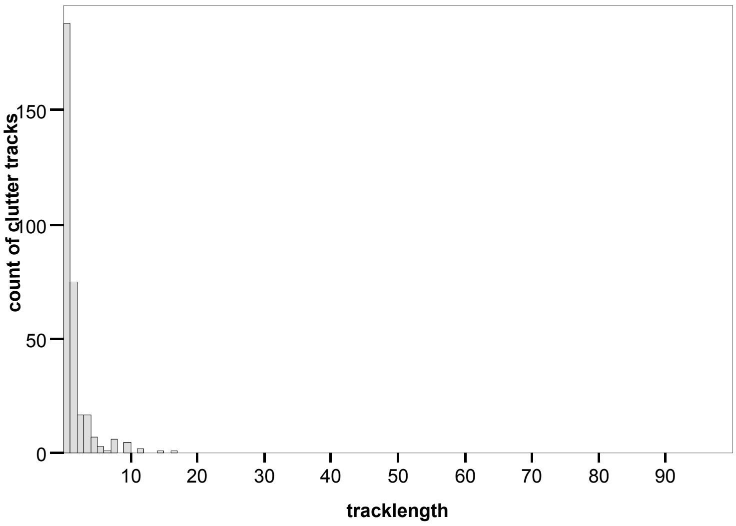


Figure III.6 Frequency distribution of tracklengths of bird tracks (above) and clutter tracks (below).

Trackquality. Trackquality is a combination of the length of the track and the consistency with which Merlin recorded this track. It is defined as the sum of tracktype-values of all echoes within a track, divided by the number of echoes within that track. A low value for tracktype indicates that the object was seen in all previous scans, a high value that it was not detected in the previous scans. Because of the predictable nature of bird flight, it is expected that trackquality is lower for bird- than for clutter tracks.

We found that trackquality was indeed considerably higher in clutter- than in bird tracks (fig. III.8). The number of bird tracks decreased strongly above a trackquality of 3.5, while the number of clutter tracks increased strongly above this value (fig. III.9). A trackquality of more than 3.5 is on those grounds considered as clutter and removed from the database. As a result, we would lose 59% of clutter (and 2% of birds) from the flagged database (605 birds and 132 clutter remaining). When data are filtered on both tracklength and trackquality, we would lose 92% of clutter and 14% of birds in the flagged data (534 birds, 27 clutter left).

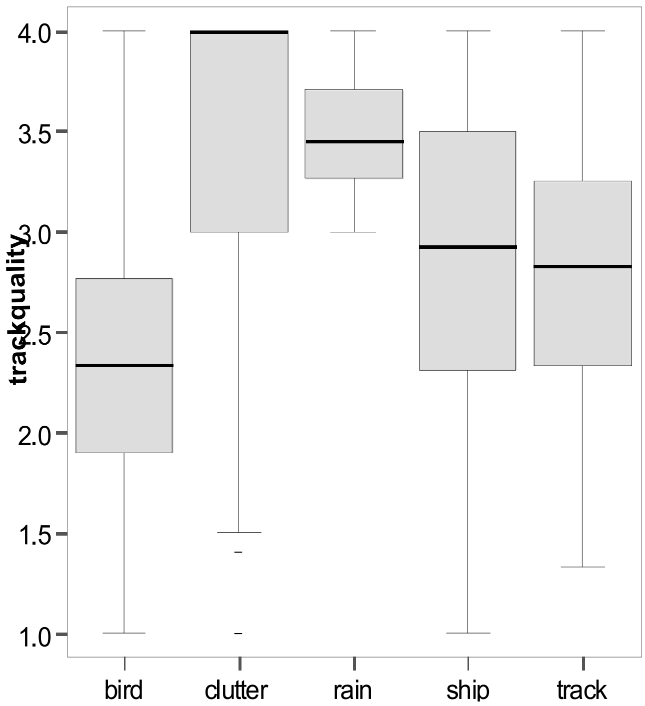


Figure III.8 Variation in trackquality of various types of radar echoes. Trackquality was lower in bird- than in clutter tracks.

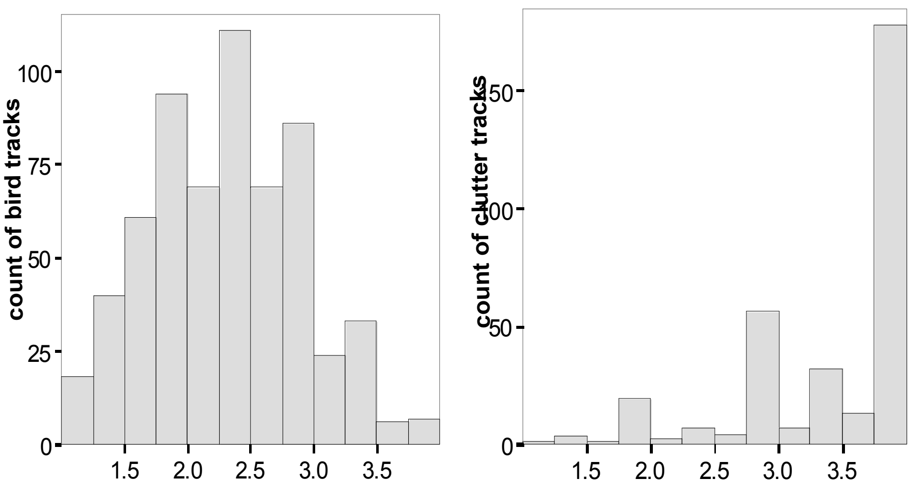


Figure III.9 Frequency distribution of trackquality of bird tracks (left) and clutter tracks (right).

Distance ratio is the total distance covered by an object divided by the distance covered between the first and the last echo of that object. Erratic tracks such as those of clutter are expected to have a higher ratio than tracks of birds that are flying in a straight line. However, there was no clear difference in distance ratios of bird and clutter tracks, neither for all tracks (fig. III.10) nor after filtering out the shortest tracks and worst trackqualities.

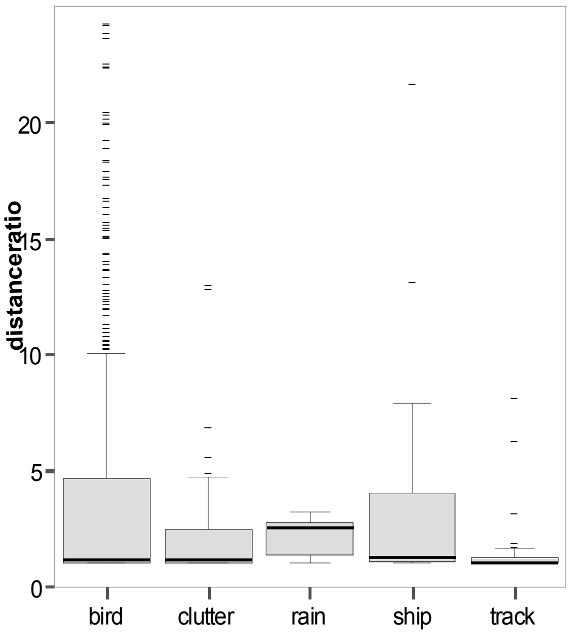


Figure III.10 Variation in distance ratio of various types of radar echoes. Distance ratio was similar in bird- and clutter tracks rather than lower.

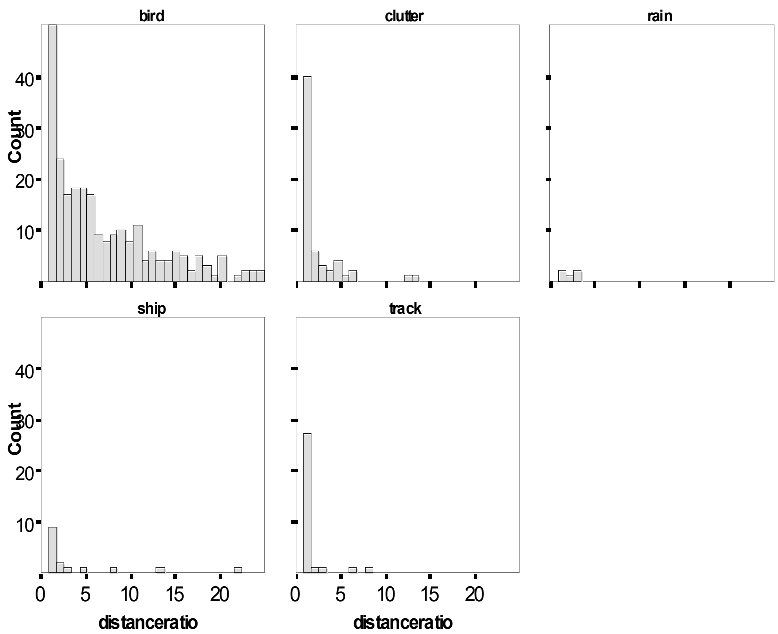
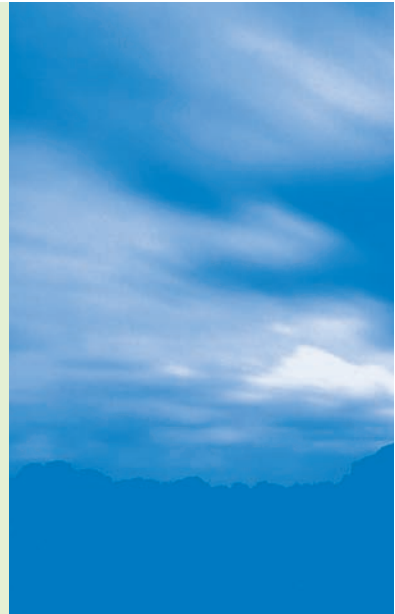


Figure III.11 Frequency distribution of distance ratios of various types of tracks.

Other parameters to discriminate between bird and clutter tracks have at this point not been found, but are expected to arise with the build-up of additional data.

Clutter removal possibilities. Because the horizontal radar data serve to show patterns in flight directions and in flight intensities, not all the bird tracks need to remain in the database. This allows for a more robust removal of clutter tracks, even if in that process bird tracks are removed as well. Consequently, with the current differentiations between clutter and bird tracks, tools for obtaining a database that shows patterns in flight directions of birds are available.



Bureau Waardenburg bv
Adviseurs voor ecologie & milieu
Postbus 365, 4100 AJ Culemborg
Telefoon 0345-512710, Fax 0345-519849
E-mail info@buwa.nl, www.buwa.nl

Appendix to report: OWEZ R 231 T1 20100810

To whom it may concern:

Within the framework of the Offshore 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 and 2008 on flight paths of birds. Before publication, the report was reviewed by Dutch energy agency Agentschap NL 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.

Aan de lezer van dit rapport:

In het kader van het project Offshore 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 en 2008 is gedaan aan vliegpaden van vogels. Voordat een rapport wordt afgerond wordt het concept voor commentaar voorgelegd aan Agentschap NL 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.

Reaction to the comments from Waterdienst and Altenburg & Wymenga on the second interim report on flight patterns of birds at OWEZ.

Karen Krijgsveld, Bureau Waardenburg, March 2010

All texts translated from Dutch by Mark Collier, Bureau Waardenburg.

The comments of Altenburg & Wymenga are presented below. In general, the comments are positive. Most of the comments concern straightforward additions to analyses and information. These will be answered in the final report, once all of the data are available. Our reaction is inserted in italics within the comments from Altenburg & Wymenga given below.

Our reaction to the comments of the Waterdienst is included in their pdf with comments.

The most important change to the 2nd interim report is the addition of a short introductory statement reiterating the fact that this is an interim report. This statement has been included as most of the comments relate to results and conclusions that can only be presented in the final report. This indicates that the nature of the interim report is not sufficiently highlighted. When considering that this is an interim report, many of the comments are not directly relevant to the present report, although they can act as useful suggestions for the final report. To this end the third paragraph to the preface can be repeated in the introduction under the heading “This report”.

Proposed addition to §1.1 of the report in italics, with the following passage:

“This report”
The report at hand is the second interim report of the effect study. It gives a summary of the results obtained thus far, from the start of the project in March 2007 until December 2008. The report shows results on species composition, fluxes, flight paths and flight altitudes, similar to the first interim report. It builds on the first interim report, updated with results from 2008.

The purpose of this interim report is to provide an overview of the results that have been obtained thus far. It is not meant to provide an analysis of the results, nor is it meant to give an exhaustive description of methods and limitations thereof, nor is it meant to present conclusions.

REVIEW
Krijgsveld *et al*. 2009: Effect studies OWEZ – progress report on fluxes and behaviour of flying birds covering 2007 & 2008

Author:	Jelmer van Belle
Commissioned by:	Waterdienst/S. van Lieshout
Authorisation:	Ron van der Hut
Date:	16-11-2009

Altenburg & Wymenga ECOLOGISCH ONDERZOEK

1. General

This report is an update of the progress report in 2008. It is based on more data than the previous progress report and focuses on the analysis of those data. Visual, auditory and radar measurements provide a lot of data a lot of data, and are generally presented in a clear way. However, by focusing on the data some aspects of the methodology seem scattered: one part about the radar –although clear - is given in an appendix while another part is in the main report. Also, many methodological decisions are not presented in this report. This is probably a conscious decision as they are presented in another report, but the report frequently raises questions to which the answer cannot be easily found. In spite of the length of the study, large year-to-year variations limit the study, and this is in balance with the conclusions drawn.
BuWa: Yes, this was indeed a conscious decision in order to focus on the results and avoid repetition of the first interim report. The methodology was extensively discussed in the first interim report and in the final report the methodology will of course be considered in detail.

2. Discussion of materials and methods

Chapter 2, Materials and Methods, deals with the study area and the various survey methods: visual, auditory and radar measurements. This chapter does not address how these measurements are integrated. We have the following questions and comments on each section.

Study area

- A 'before' analysis in the area of the wind park relative to the expected movements of birds would help the reader interpret the current results.

BuWa: Prior to the study almost nothing was known about low altitude flight patterns at sea. The research fills an important gap in that sense. The comment is a good suggestion for an addition to the introduction; here we will add a paragraph about the general patterns of flying birds in the North Sea to the final report.

- What is the common distance between the wind turbines?

BuWa: c. 650 m within rows and 1000m between rows. This is added to §2.1.

Visual

- The description of the panorama scans is comprehensive. It is correctly noted that this methods provides estimates of densities. How these data serve as calibration for the radar data, in which the vertical radar is the primary source of data and provides the flux, is not elaborated.

BuWa: This is a step that will be given once the data are complete and will be discussed in full in the final report. The panorama scans give minimum fluxes and species composition in percentages.

- The method for moonwatching is not given in this part.

BuWa: True, there is, however, a short description of what it is and three references.

Auditory

- The auditory observations are in the report under the section for visual.

BuWa: read as "man-made".

- What is the height range?

BuWa: This is a sensible addition to §2.3.4. The range is not exactly known, but is limited and estimated at a maximum of 100 m.

- Which species were heard?

BuWa: This is discussed in §4.3

- What is the influence of time of day?

BuWa: This will be in the final analysis of the entire dataset. This question will be addressed by more than just auditory data.

- What is the influence of the landscape and the distance to the migration-destination?

BuWa: Ditto. The research is only carried out at sea; detailed comparisons of patterns on land (other than flux) are not given.

- What is the influence of group size?

BuWa: The question is not clear. On what? Nocturnally migrating birds frequently migrate individually.

Radar

- The choice of radars is only discussed briefly as large parts refer to another report. This report is older and it is not clear whether any changes, and if so where, have been made with respect to the original approach.

BuWa: The changes since the baseline report are given in the first interim report. Any differences and the consequences of these on the gathered data will be discussed in the final report, once the radar data have been analysed.

- In one instance such a difference with the original approach is clear, as an earlier paragraph states that the settings for the horizontal radar were changed in October 2007. What are the reasons for this and how have these changes affected the following:

BuWa: Relates to improving the settings based on experience gained during the first half-year of research. Improved detection of birds. This will be clarified in the final report. The consequences of all software changes affecting the radar (including relative to T0) will be given in the final report.

  - detection of large versus small birds?

  BuWa: the same

  - greater versus smaller distances to the radar?

  BuWa: better, specifically closer to the radar

  - detection between sea clutter?

  BuWa: the same, but better suppression of clutter

  - detection capabilities at very high and low altitudes?

  BuWa: the same

- Radar specifications are mentioned as indicators, but:
  - what is the height range and beam width? (graph?)

  BuWa: Hypothetical figures can be calculated and added. However, actual figures may differ and are not known. Possibly estimates of these figures can be made using the radar data. This can be estimated only after the cleaning up / filtering of radar data and will be addressed in the final report. We propose to present the calculated beam widths only then.

  - what are the expected differences between the S-band horizontal and X-band vertical radars?

  BuWa: This is described in §2.4.1

- How is flux calculated?

BuWa: This is in §2.4.3 and the second paragraph of chapter 4.

- The comparison between automatic data and the images of the radar screen are very useful but provide no validation. The question is which of the two systems is better as both false negatives and false positives occur? i.e. when birds are missed and when echoes are wrongly classified as birds.

BuWa: The example (§3.1.2) is about verifying the extent to which the tracks registered by Furuno are also registered by the Merlin software and recorded in the database, thus validating the Merlin software. This is carried out in two steps: Step 1 = check of tracks seen on the Merlin screen recorded in the database. Step 2 = check of tracks recorded by Merlin compared to the number of tracks seen on the 'raw' radar screen. Therein, we assume that the Furuno radar screen accurately depicts the situation with regard to bird tracks. The limitations of use of radar in general are not relevant at this stage. The above *will be discussed in the final report.*

- The possible detection of insects is not discussed; this is a well-known source of false positive observations, also along the North Sea coast.

BuWa: This is discussed in §2.4.3 and §7.2 6th point. A comment that insects were only detected directly above the vertical radar is added to §2.4.3. This area is not included in analys. Insects were not registered on the horizontal radar.

3. Discussion on measured fluxes

In chapter 4, 'Results on fluxes', the flux observations from the vertical radar, moonwatching and auditory observations are presented, along with the species-specific densities from the panorama scans, and the horizontal distribution of bird densities around the wind park.

In general, this part is presented in a clear fashion. The differences between diurnal and nocturnal fluxes raise the question whether the relatively low fluxes during the day could be explained by group size; a radar echo during the day could involve a number of individuals.
BuWa: Yes, this could be. A comparison with visual observations and between different times of the year (migratory and non-migratory periods) may provide some insight into this. This will be done in the final report.

For visual observations the possible effects on the spatial densities are clearly described. It would seem to be clearer to combine this with the discussion about flight paths in the next chapter.
BuWa: It was deliberately decided to present the results for fluxes, flight paths and altitudes separately.

4. Flight patterns

In chapter 5, 'Results on flight paths', the spatial distribution of bird echoes is discussed. The data are based solely on visual observations. We have two specific questions over this, namely:

- Under the sub-heading 'Spring' in paragraph 5.1 it is stated that the flight paths mainly concern land birds. On what is this based? In table 4.3 the species-specific densities are given as 'gulls' 0.56 and 'land birds' 0.49. Therefore, why is the observed patterns not of 'gulls'?

BuWa: This conclusion is based on simultaneous visual observations. This will be reiterated in the text but does not lead to any changes in the results or discussion. This will be elaborated in the final report once more data on fight patterns are available. As previously stated these preliminary results are based on limited data.

- On the same page and under the sub-heading 'Summer' the flight paths are not discussed in relation to time-of-day. This is a shame as earlier measurements from IJmuiden with the 'Flycatcher' radar showed considerable variation during the day. A single table with species specific summaries would provide an insight into these.

BuWa: A more detailed analysis would certainly be interesting but can only be given once sufficient data are available for such a detailed analysis. The data from the horizontal radar are more appropriate for this purpose than visual observations.

5. Flight heights

Flight heights are discussed in chapter 6. Previously in the text it is mentioned that the detection is influenced by height. This seems to us an important aspect to address.
BuWa: It is not completely clear what is meant here. It is discussed in the first paragraph of chapter 6, in the first paragraphs from chapter 3 and §3.1. Information over the detection range and beam width will be useful additions. These, as has already been discussed in 2 - 'Radar', will be included in the final report. From observations and calculations during the baseline study it is known that the radar settings do not hinder the registration of birds.

In addition is the question as to the detection capability below 100 m and what effect does sea clutter have on the image of the vertical radar?
BuWa: see page 35. Because the vertical radar is limited to 0.75 nm the detection capability / precision is greater than at larger ranges (e.g. as is used by stronger radars). The mentioned detection capability thus is only limited in the lowest air layer just above the sea, between about 10 - 25 m. Within this zone there may indeed be low-flying birds that are not detected against the background 'noise' of waves. However, fluxes are presented as percentages of birds flying at different height zones. Therefore, the percentage of birds flying in the lowest zone, which is below the height of the turbines is under estimated while the number of birds in the higher 'risk' zone is over estimated. In reality there will be fewer birds flying in this 'risk' zone than calculated and therefore, the method gives a result that is on the safe side.

In this chapter there is reference to the effect of why more birds are recorded in one sector than another. This is possibly correct, but the conclusions over flight direction, although a very important part of the explanation of the difference in numbers, seems somewhat far-fetched because the spatial layout of the wind park could also play a role in the observed flight directions.
BuWa: See p151 in the T0 (baseline) report, where this effect is clearly demonstrated. See also page 36 in §3.1.2. The comment over the results presented on page 80. These preliminary results indicate that the flight direction can play a role in the calculated fluxes. Conclusions on flight direction are based on preliminary results and as such the use of 'possible' is used whenever appropriate. The final analysis, discussed in the final report should shed some more light on this.

6. Conclusions and discussion

Despite the above mentioned methodological comments it seems to us that the conclusions drawn in chapter 7 and the proposals for future observations are realistic.